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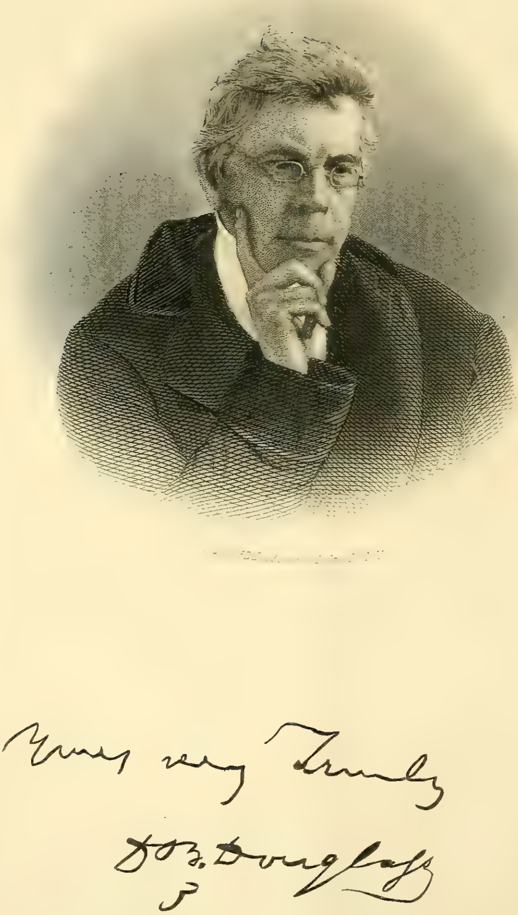
Yours very Truly

VAN NOSTRAND'S
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MAJOR DAVID BATES DOUGLASS.

A BIOGRAPHICAL SKETCH.*

David Bates Douglass, son of Nathaniel and Sarah Bates Douglass, was born at Pompton, New Jersey, March 21, 1790.

His early education was carefully and ably superintended by his mother until he was prepared to enter Yale College, from which he graduated with high honors in 1813.

From Yale College young Douglass went directly to the Military Academy at West Point, and soon entered the military service of the United States as an officer of the Engineer Corps. In 1814 he was detailed with his command in the Northwestern campaign of that year. He performed brilliant service during the siege of Fort Erie, for which he received the commendation of General Gaines, and was further rewarded by promotion to a captain by brevet.

About 1816, Captain Douglass received the appointment of Assistant Professor of Natural Philosophy in the Military Academy, and the succeeding 15 years were spent by him in active official duties at West Point and in civil engineering.

In the practice of this latter profession, he made, in 1826, surveys and estimates for a canal from Conneaut Lake to Lake Erie. The same year he made surveys for the location of the Upper Delaware canal. A revision of the surveys of the Sandy and Beaver canal, of Ohio, followed by an examination and survey of the vicinity of Philadelphia, to establish the terminus of the Pennsylvania Railroad, were professional services performed about the same period.

In November, 1828, Major Douglass made an examination of the line of the Morris canal, of New Jersey, with reference to the employment of inclined planes instead of locks. His subsequent report and plans led to a professional engagement in the service of the Company, and his resignation of his chair at the Military Academy. This occurred in 1831.

The inclined planes were soon brought into successful operation, and were justly regarded as an important engineering achievement.

In 1832 he entered the New York University, its first Professor of Natural Philosophy; but finding his professorship to interfere with his engineering pursuits, he relinquished this position after one year's duty, but was borne on the roll of the institution as Professor of Civil Engineering and Architecture, and during the year of 1836 and 1837 he delivered a course of 80 lectures on these subjects.

In 1833 he was called upon to survey the route for the Brooklyn and Jamaica Railroad on Long Island, which he completed in the winter of that year.

An act was passed by the New York Legislature, February, 1833, authorizing surveys and estimates for supplying the city of New York with water. Imme-

* Lives and Works of Civil and Military Engineers of America, by Chas B. Stuart, C.E. New York: D. Van Nostrand.

diately after the passage of this Act, the Board of Water Commissioners appointed Major Douglass and Canvass White, engineers. But the professional duties of Mr. White in the State of New Jersey preventing him from making the examination desired by the commissioners, the whole duty devolved upon Major Douglass, who completed the preliminary surveys in November of that year, and made his report soon thereafter; regarding which the commissioners, in their report of November, 1833, say:

"For a more particular and detailed description of the surveys, and other important information on the subject, the commissioners beg leave to refer to the able and lucid report of the engineer, Major D. B. Douglass, hereunto annexed."

In the report referred to, Major Douglass recommended the use of the Croton river and its tributaries to be conveyed to the city by an enclosed stone aqueduct, and estimated the length of the same from the confluence to the receiving reservoir at Manhattanville at 37 miles, and from the latter to the distributing reservoir, $5\frac{1}{2}$ miles. The report states that "the structure of masonry has been adopted instead of iron pipes on the ground of its superiority in point of economy, durability, and efficiency."

Also, "the crossing of the Harlem river is proposed to be effected by means of an aqueduct bridge, 1,180 ft. long from abutment to abutment, consisting of 9 semicircular arches. The height of the structure, from the water-line of the river to the water-line of the aqueduct, would be 126 ft., exclusive of the hydraulic foundations, which would be from 10 ft. to 20 ft. more. A structure adapted to these dimensions would be, of course, a work of considerable labor and expense, but by no means of paramount difficulty in either respect."

A feasible and durable plan for supplying the city of New York with water in abundance for not only its population at the time, but for the anticipated rapid increase in the future, had, since the year 1820, agitated the public mind, and various methods had been devised, and plans reported upon, none of which, at this period, proved acceptable to the citizens.

Major Douglass at once comprehended the importance of the undertaking, both as to the health and its bearing upon the future growth of the city, and earnestly devoted himself to the successful accomplishment of the work.

The first investigations were directed to finding an abundant and unfailing supply of pure, wholesome water, and at an elevation that would allow of its flow into the city by its own gravitation, and with a head that would supply the upper stories of the buildings; and that could be used from the hydrants for the extinguishment of fires.

With these purposes in view, Major Douglass commenced his explorations and surveys in May, 1833, and in the following month he reported examinations of "all the chief tributaries of the Croton river and several of the remarkable reservoirs from which they derive their supply; generalizing, meanwhile, the slope of the left bank with reference to the various routes of exit in the direction of the city. This is indeed a wonderful country for water, whether we regard the abundance or the purity of its fountains; and the intervening obstacles appear less formidable than I had supposed them to be."

On the completion of the preliminary surveys, and an estimate of cost, Major Douglass submitted a report to the Board of Commissioners, and the feasibility of the plan was so clearly shown, that the sanction of the Legislature was readily obtained in an Act of May, 1834, for proceeding with the construction of the work. Douglass was appointed Chief Engineer.

As early as October, 1835, the surveys necessary for the location of the Croton dam were completed, but in opposition to the judgment of the chief engineer, the Commissioners changed the location to Garretson's Mill, with a graduation of 40 ft. as its height.

Throughout his term of service Major Douglass found great difficulty in maintaining proper discipline in his corps of engineers, from the limited power with which the Commissioners invested him. They were unwilling to admit the necessity of an engineering department, and while Major Douglass fully realized the magnitude of the undertaking, the Board regarded it as little more than an extended job of plain masonry, that might easily be constructed upon very economical principles.

There existed widely different views of economy and discipline between the first Board of Commissioners and the chief engineer, which finally led to a change that was universally regretted by the numerous friends of Major Douglass.

In October, 1836, he was removed from the charge which his experience and high scientific attainments so ably qualified him to prosecute to completion. His surveys, plans, drawings, and reports were submitted to the Board, and by them adopted, and the construction of the work passed into other hands.

The various surmises and rumors upon the abrupt and unexpected discharge of Major Douglass by the Board of Commissioners, in many instances prejudicial to his reputation, and from which he would not undertake to exonerate himself, and although urged by several members of the Board to do so, is fully explained in the following letter to one of the Commissioners, in 1840:

"In addressing a few lines to you on the subject of the unpleasant controversy which occurred in 1835–6, I cannot think it will be necessary to say much in the way of vindicating myself.

"You did not indeed witness but a very small portion of the violence and overbearing of Mr. Allen's conduct to me, but enough must have been seen to assure you that it was wholly as involuntary as it certainly was free from personality on my part.

"Should you have any doubts on this point, they cannot but be removed when I assure you that, painful as the controversy was in itself, and disastrous as the consequences have been to me to be thus thrown out of employment suddenly and unexpectedly, at a time when all other resources were unavailable; to have a great work, the only one I had thought worthy of my ambition, taken out of my hands after being matured in all its most difficult features; my professional character—the capital on which I and many others depended for our daily bread—assailed,—to have experienced all this at the hands of Mr. Allen, while my friends were importuning me to write, and members of the Common Council urging me to furnish statements, yet I resisted all influences and published not a line.

"It would have been very easy to show the unsoundness of every allegation brought against me, either in the Commissioners' report or in the papers, from 1835 to the present time. I pledge myself to do this for you, or for the new Board, whenever you or they may desire it; but I abstain from doing it before the public, simply because I resolved that no consideration of a personal kind should induce me to do any thing to disturb or interrupt the progress of the great work. Let me beg you to consider the exceeding injustice of the assertion often made by Mr. Alleys and Mr. Allen, that I had been a partisan in opposition to the Water Commissioners. Had I been such a partisan these gentlemen would have heard from me in different style, but I have not been."

In 1837 and 1838, Major Douglass made an examination and report on the hydraulic power of the Monmouth Purchase; also a reconnoissance of the coal region of the Upper Potomac; and from 1837 to 1840, he was occupied in laying out the grounds of Greenwood Cemetery.

This beautiful locality was observed by him as highly appropriate to such a purpose, while engaged in the construction of the Brooklyn and Jamaica Railroad. These surveys, though they had no reference originally to this object, were incidentally applied to it in the public lectures which he was called upon to deliver in Brooklyn, about the period of 1835. The original cemetery comprised only 178 acres, the ground declining in some places to valleys of less than 20 ft. above tide water, and in others rising to hills of more than 200 ft. Mount Washington is 216 ft., being the most elevated ground in Kings County, and one of the highest points on Long Island. A heavy native growth of fine old forest trees suggested the name of "Greenwood" as appropriate for this cemetery. The artistic skill and classic taste of Major Douglass is beautifully illustrated in the laying out of this quiet and romantic home for the dead.

It contains 413 acres of hill and dale. Mount Auburn is beautiful, Laurel Hill has its charms, but none of the cemeteries of the country can compare with Greenwood in the wonderful grandeur of its views, its variety of landscape, and its extent.

The avenues extend for nearly 25 miles, and it has several hundred miles of walks and paths within its enclosure.

From 1839 about $5,000,000 had been received, and nearly all of it expended on improvements. To grade the grounds, and lay out the avenues and walks was an immense work, and it has been continued through many years, not being entirely completed even now.

The principal entrance to Greenwood is on Fifth avenue, South Brooklyn ; the gateway is a magnificent and costly structure of Gothic form, and constructed of the finest brown sandstone.

It is very large, and presents an imposing and massive appearance.

This gateway is probably the finest piece of architecture of its kind in this country.

In his letter of resignation to the Board of Trustees of Greenwood Cemetery, of which he was President, tendered in January, 1841, Major Douglass remarked: "The local organization and the laying out of the grounds is now essentially completed. To have left this in an imperfect and unfinished state would have incurred the loss of much previous labor. I have felt it imperative, therefore, to remain in office at all hazards until it was finished. It has been a work of much greater labor than I supposed when I commenced it. The extent as well as the varied features of the ground have called for long-continued, oft-repeated, and very careful study; and this I have given it, but with what effect cannot be seen until the design shall have been in some degree carried out by the opening of the avenue."

The immediate cause of Major Douglass's resignation was his acceptance of a call to the Presidency of Kenyon College, in Ohio.

Before leaving for his new charge he submitted the plans and drawings for the improvement of the cemetery grounds to the Board. Mr. J. A. Perry, of Brooklyn, writing upon the subject a year subsequently, observed:

"Anything about Greenwood, and especially its long-desired success, would not be an uninteresting theme to its old and faithful friend. We are now opening our avenues through the forests, and they open most beautifully. Having, providentially it would seem, nothing to occupy my time since March last, I have devoted it all to Greenwood ; delightful work, now that it is crowned with success, has it been. In June we propose to consecrate our grounds. It is but meet that one who has contributed so greatly to the establishment, and developed so admirably the beauties of Greenwood, as we delight in thinking you have done, should participate in the ceremonies of that occasion. Can you not be with us?"

Major Douglass replied as follows:

"Believe me, you could not have done me a greater favor than in thus communicating the future brightness of Greenwood. My own associations with it are as fondly cherished, and all my recollections of it as fresh as ever. How delighted would I be could I promise myself, with any degree of assurance, the pleasure you hold up to my view so temptingly, of joining you in the approaching consecration ; but I fear it is impossible.

"I can realize how delightful a relief the Greenwood improvements must be to your mind. Pressed and borne down as I frequently was while there engaged, its associations were always vivifying and gladdening to me. Its deep shades and quiet retreats, its old oaks and green cedars, the umber foliage during its Indian summer, the setting sun from Mount Washington, its breezes and its flocks of birds—everything about it was unlike anything else in this world. I yearn to see them again. Indeed, everything about Brooklyn continues to interest me as much as ever. No lapse of time can efface the smallest of the recollections by which it is endeared to me."

The following letter from Professor Olmstead, of Yale College, to Rev. Malcolm Douglass, indicates the feelings of those with whom Major Douglass was early associated, and the deep interest his classmates manifested in his subsequent varied and brilliant career:

"I send herewith the interesting letter addressed by your honored father to his classmates at their thirty years' meeting, in 1843. It was read in the meeting, and listened to with lively interest, but with deep regret that the writer could not make one of our most delightful party. Professor Douglass was justly regarded as a member who had done great honor to his class, by his gallantry in the service of his country during the war of 1812, and by his eminence as a man of science, particularly by the great public works which he projected, several of which remain as durable monuments of his genius and skill."

Major Douglass continued his association with Kenyon College until 1844, when he returned to the East, and occupied his time until 1848 in the active discharge of various duties, among which were the planning and laying out of the Albany Rural and of the Quebec Cemeteries; the survey of the Albany Water Works; the drainage and graduation of South Brooklyn; the planning a supporting wall for a portion of Brooklyn Heights; in examinations and reports upon the best method for supplying that city with water, and the laying out of the grounds of the New Brighton Association, of Staten Island. In 1848 he was called to the chair of mathematics at Geneva (now Hobart) College, which he accepted, although other propositions were laid before him with offers of greater compensation.

Major Douglass died at his residence in Geneva, New York, October 21st, 1849, from the effects of a paralytic stroke, at the age of 59 years. His remains were deposited at Geneva. After the lapse of little more than 12 months they were removed to the Greenwood Cemetery, in answer to a request based upon the following resolution by the Cemetery Board, December 2d, 1850, as follows: "*Resolved*, That two lots for the use of the family of the late Major Douglass be designated by the Standing Committee, and when the remains of Major Douglass are deposited therein, the said committee shall cause the lots to be suitably enclosed, and an appropriate monument to the memory of Major Douglass erected thereon." His remains now repose in that beautiful Necropolis, to the creation of which his admirable genius so largely contributed.

No monument to his memory has yet been erected there. At this period the only public memorial of his life and death is to be found in the large and richly stained monumental windows of the south aisle of Trinity Church, Geneva, upon which is traced the following inscription: "To the glory and praise of God. The children of the late David Bates Douglass, filled with affection for his memory, and with devout gratitude for his paternal precepts and Christian example, erect this memorial window."

Major Douglass in stature was several inches above the medium height, slender, but finely proportioned, with an energetic, earnest movement, and distinguished military presence.

His features, without being regular or handsome, were strongly marked and striking; his hair was dark, and his eyes black, large, and restless; his voice deep-toned and firm. With brilliant conversational powers he combined a manner of address, polished, quiet, and unostentatious. He was a favorite of the drawing-room and of the family circle.

Religious in his proclivities, he superintended with pious vigilance the education of his family. His two eldest sons were graduates of Kenyon College.

The eldest, Charles Edwards, was destined for the church. After graduating, he passed regularly through the University course at Trinity College, Hartford, Connecticut, and is now the Rector of St. Paul's Church, Windsor, Vermont.

From him many valuable papers were obtained and used in the preparation of this imperfect sketch of his distinguished and venerated father. The fourth son, Henry, after going partly through a college course, entered the U. S. Military Academy at West Point, and graduated in 1851. Major Douglass also left four daughters.

One might deem the years of Major Douglass comparatively few in number, and his death premature, but in glancing at the leading events of his life from his early graduation at Yale College to the period of his death, with the reflection that within the narrow limits of a biography of this nature, only the professional incidents could be recorded, he had lived long in useful mental exertion.

Every hour had been occupied in earnest labor for the cultivation of others, or in plans for the military defence or public improvements of his country. While Professor of Architecture of the University of the City of New York, the university buildings were constructed from his design, being the first introduction into this country of the Elizabethan style.

The following tribute to the peculiar qualities of Major Douglass as a teacher, and his character as a Christian, is from the sermon of the Rev. Dr. Hale, President of Hobart College, upon the death of Major Douglass, and coming from one who was so well qualified to judge, and who had been associated with him as a teacher and a neighbor, gives it greater value and force :

"By the caste of his mind and the qualities of his heart, no less than by the extent of his attainments, he was fitted to be a teacher. He had a rare facility in acquiring knowledge and making himself master of it in all its broadest principles and minutest details; but it seemed to be his great pleasure and the peculiar tendency of his mind to impart it.

"He loved books, but if I may judge from my acquaintance with him, which was intimate, he was less a reader than a thinker. He looked reverently upon books—books which he desired and sought—and read them, not for amusement, but a serious occupation of the mind and heart. He read, therefore, not superficially, but intently, as he would have listened to the voice of a teacher in answer to earnest and importand inquiries. He possessed great powers of analysis, which he exercised not in a captious or doubting spirit, but that he might better know and form the material whereon to exercise that faculty of his intellect which was more peculiarly his characteristic, the constructive talent.

"Hence, his views, his opinions, his aims, were all definite. Hence, the depth and clearness of his instruction. Hence, in conversation he was still the teacher, and without any of the forms of argument, his discourse, clear in its own light, was full of information."

NOTES ON FIRE-BRICKS.

By Lieut. G. E. GROVER.*

Fire-bricks are so named from their property of comparative infusibility when exposed to very high temperatures. I say *comparative,* because no known material seems to enjoy absolute immunity from decomposition under the attacks of unlimitedly intense heat. Even the nominally infusible substances (pure silica, alumina, lime, and magnesia ; the natural varieties of rotton-stone—a very aluminous silicate of alumina, decomposed from rock ; and the silicates of magnesia, talc, asbestos, steatite or soap-stone), have been known to succumb in the flame of an oxyhydrogen blowpipe, or between the poles of a galvanic battery.

It is, however, clearly unnecessary to discuss in this paper any materials but those practically obtainable in large quantities ; and of these the chief components in Great Britain are the so-called fire-clay, with the exception of the silicious Dinas *rock* in the Vale of Neath, Glamorganshire, to which fuller reference will be made hereafter. Clays proper are chemical compounds, occurring under different phases in numerous geological formations, and consisting of hydrated silicates of alumina, either alone or in combination with silicates of potash, soda, lime, magnesia, iron, manganese, etc. Though a sediment from water (being, in fact, decomposed rock, characterized by a very minute division of constituent particles), they are tough and plastic, differing from mud in these respects, as well as in the absence of vegetable and animal matters. The plasticity and tenacity of argillaceous earths are due to the prominence of the ingredient alumina (which has a strong affinity for water), and are diminished by the presence of iron, lime, and magnesia. Clays appear to be the result of the slow decomposition by water of felspar, or some similar material, containing either potassa or soda.

The so-called fire-clays owe their refractory properties to a variable absence —differing, that is to say, in different clays—of lime, oxide of iron, and the alkalies of magnesia, potassa and soda. In refractory bricks, formed of baked fire-clay, the silica may be considered as a passive ingredient, acting mechanically to prevent excessive contraction, whilst the alumina forms the cement which binds the particles together.

The following is a list of the usual constituents of fire-clay, with their respective chemical symbols :

Silica (or silicic acid)............... $Si\,O_2$
Alumina (or sesquioxide of aluminum)......................... $Al\,O_3$
Peroxide (sesquioxide or red oxide) of iron....................$Fe_2\,O_3$

* Extract from a paper presented to the Corps of Royal Engineers.

Lime (oxide of calcium).......... Ca O
Magnesia (oxide of magnesium)... Mg O
Potassa (oxide of potassium)..... K_2O
Soda (oxide of sodium)...........Na_2O

and the following table details, for the sake of example, their proportions found in chance samples of several well-known classes of English fire-brick.

	Silica.	Alumina	Peroxide of iron.	Lime.	Magnesia.	Potassa.	Soda.	Titanic acid.	Total.
Stourbridge	65.37	26 48	5 68	.28	.33	1.26	.30	.30	100.00
Plympton, Devonshire.......	74.02	21 37	1.94	.40	.36	.82	.09	....	100.00
Newcastle-on-Tyne..........	64.63	29.78	3.23	.42	.41	1.09	.24	.20	100.00
Burton-on-Trent.............	58 08	36.89	2.26	.55	.14	.20	1.88	....	100.00
Wortley, near Leeds..........	65.25	29.71	3.07	.40	.61	.43	.12	.41	100.00
Poole, Dorsetshire...........	59.35	34.32	2.35	.43	.22	3.33	....	....	100.00
Hedgerley, Buckinghamshire.	84.65	8.85	4.25	1.90	.35	....	....	....	100.00
Kilmarnock, Ayrshire........	58.92	35 65	2.49	.39	.35	1.14	1.06	....	100.00
Dinas, Glamorganshire.......	97.62	1.40	.49	.29	....	.10	.10	....	100 00

It should be observed, however, that the infusibility of any substance depends, not merely upon the chemical natures of its constituents, but also upon the manner in which those constituents are combined with one another. For example, granite, *per se*, is infusible at ordinary high temperatures, whilst pounded granite (or, in other words, a fine powder of quartz, felspar,, and mica, mixed in the same proportions) can be readily melted in the same degree of heat. The porosity in structure brought about by a coarseness of elementary particles would seem to add to the chemical infusibility of a material.

A most important physical peculiarity of clay—second only in importance to the property of plasticity—is its behavior on exposure to high temperatures.

It is well known that, as a general rule, all bodies are expanded by heat. Clay, however, appears to be an exception to this rule, being a mechanical mixture and not a homogeneous body; and it was observed by Mr. Wedgwood, that alumina, or clay in which alumina predominates, on being exposed to a red heat, begins to contract, and, as the heat increases, continues to contract regularly until it finally vitrifies, and so (by its permanent diminution in bulk) furnishes an approximate indication of the temperature to which it has been subjected.

Hence the Wedgwood pyrometer, which, by a comparison of the diminution in diameter of small cylinders of aluminous porcelain clay, placed between cylindrical brass rods forming a graduated gauge, supplies an empirical text of the degree of heat which those cylinders have sustained. It is proper, however, to remark that, as clay is a heterogeneous substance, and its contractions are not of necessity regular at different temperatures, this pyrometer—though useful for most practical purposes—fails to record the degrees of heat with precise accuracy; and there has yet to be devised a thermometer which will indicate with absolute exactness the very high degrees of furnace temperature.

Again the moulds of bricks are usually made larger than the intended products by abont $\frac{1}{10}$ or $\frac{1}{12}$ of each dimension, that being the ordinary proportion in which the dimensions of the brick shrink in burning. The cause of this str uge property of clay is, I believe, still a matter of question.

By some it is supposed to result from an expulsion of the water of combination, and a consequent contraction of the primary pores, which produces an increased density of the mass. By others it is ascribed to an actual rearrangement of the constituent atoms by the influence of heat, which brings them into more intimate union. But, whatever be the cause, the property is important, and noteworthy in its bearing upon the present subject of investigation.

Fire-clays able to resist exposure to a high temperature without melting or becoming, in a sensible degree, soft and pasty, occur in various geological formations, and they abound in the coal measures in the carboniferous system. The following are a few of the best known localities in this country whence fire-clay is extracted : the valley in Derbyshire, between Burton-on-Trent and Ashby-de-la-Zouch; the Southbridge district, in Worcester and Staffordshire (including Dudley, Tipton, Gornal, etc.); Newcastle-on-Tyne, in Northumberland; Wortley, near Leeds, in Yorkshire (including Elland, Storr's Bridge, Stannington, etc.; Wolverhampton, in Staffordshire; Poole, in Dorsetshire; Newport, in Monmouthshire; Kilmarnock, in Ayrshire; and Glenboig, at Coatbridge, near Glasgow, in Lanarkshire. To these should be added, as sources of our most celebrated fire-bricks, the aforesaid Dinas rocks, in the Vale of Neath, Glamorganshire; the *kaolinitic* refuse from porcelain clay at St. Anstell's, Cornwall, and Plympton, Devonshire; and a peculiar stratum of sandy loam, known as "Windsor loam," overlying the chalk at Hedgerley, a village about five miles north of Slough, Buckinghamshire, whose "red rubbers," were, in the times of our grandfathers, thought to possess surprisingly refractory powers.

In the following table is shown the percentage of the three most important constituents of these different kinds of fire-bricks, which have been practically tested in the Royal Arsenal furnaces, and analyzed by Mr. Abel, F. R. S., Chemist to the War Department. The maker's names are, for obvious reasons, omitted; but samples of most of these fire-bricks are to be seen in the School of Military Engineering at Chatham:

	Maker.	Silica.	Alumina.	Peroxide of Iron.	Alkalies, Waste, etc.
Stourbridge	A	65.65	26.59	5.71	2.05
Ditto	A	67.00	25.80	4.90	2.30
Ditto	A	66 47	26 26	6.63	.64
Ditto	B	58.48	35.78	3.02	2.72
Ditto	C	63 40	31.70	3.00	1.90
Newcastle	F	59.80	27 30	6.90	6.00
Ditto	G	63 50	27.60	6.40	2.50
Burton-on-Trent	L	56.63	35.31	2.99	5.17
Wortley	N	65 20	29.69	3.07	2 04
Poole	P	68 60	23 60	4.70	3 10
Plympton	Q	75.89	21 61	1.96	.54
Ditto	Q	76 70	20 10	1.70	1.50
Hedgerley	R	84 65	8.85	4.25	2 25
Holytown	S	59.48	31.45	6.90	2.17
Dinas	T	96.20	2.00	.28	1.70
Kilmarnock	V	59 10	35.76	2.50	2.64
Glenboig	X	62.50	34.00	2.70	.80

Experience with these samples justifies the general assertion that the refractory values of fire-bricks vary inversely with the amount of iron contained in them; and, as a general rule, the presence of 6 per cent. of peroxide of iron warrants the absolute rejection of a fire-brick. This component usually takes the form of little black specks or mottled particles which are embedded in the material, and can be plainly detected upon breaking the brick.

The essential qualities of a good fire-brick may, I think, be classified as follows: *Infusibility*, *regularity of shape*, *uniformity of composition*, *facility for cutting*, *strength* and *cheapness*.

The property of *infusibility* has already been touched upon in this paper; and it seems to forbid in the brick's composition so much as even 5 per cent. of peroxide of iron, or 3 per cent. of combined lime, soda, potassa, and magnesia. Generally speaking, a fire-brick should contain either silica or alumina in excess, according as it is intended for exposure to extreme heat, or for a possible contact with metallic oxides, which would exert a chemical reaction, decomposing it and acting as a flux. Thus, in theory, the arches of a furnace should be built of silicious bricks; its sides, bridge, and neck of aluminous bricks. Dr. Percy considers ("Metallurgy," p. 235) that, to boast properly of the quality of infusibility, a fire brick must well resist sudden and great extremes of heat; it must support considerable pressure at a high temperature without crumbling; it should not melt or soften in a sensible degree by exposure to intense heat long and uninterruptedly continued; and it should withstand, as far as practicable, the corrosive action of slags rich in protoxide of iron. He recommends as a test, that the fire-clay should be formed into small sharp-edged prisms, which, on being enclosed in a covered crucible and subjected to an extreme temperature in an air or blast furnace, would denote a very high degree of refractoriness if the edges remained sharp, an incipient fusion of the material if the edges are rounded, and a thoroughly inferior quality of the fire-clay if the prisms were melted down.

M. Brongniart recommends the following process of test ("Traité des Arts Ceramiques," tom. 1, p. 342 : "Si on veut juger la qualite refractaire d'une brique, c'est de faire un petit massif de six ou huit de ces briques sur deux rangs, et de l'exposer, un rang en evant dans un four a porcelaine a l'entree du feu dans le four. Le poids affaisera les inferieures si elles sout seulement ramollissables. Le rang anterieur ne doit pas entrer dans le judgement ; il est toujours attaque, quelque refractaire qu'il soit ; mais il sert a garantir le rang posterieur de l'action de la potasse des cendres a laquelle la terre la plus refractaire ne peut resister. C'est donc sur les alterations de ramollissement, de fusion, ou de boursouflement du rang postérieur qu'on peut juger la qualité refractaire d'une brique. Aucun moyen d'analyse ou d'essai en petit ne peut suppléer à ces véritables essais techniques." It may be remarked, however, that in this investigation, analysis, theory, and practice nearly always agree pretty closely.

In many works there is adopted the rough and ready, but very efficient mode of comparing the relative qualities of fire-bricks by placing them side by side upon the bridge of a reverberatory furnace, where they are subjected to the same heat and the same corrosive action of the fuel ; and show very clearly, after a few days or weeks firing, which brick can best withstand these destructive influences under precisely similar conditions. I think this test is even superior to those suggested above. The corrosive action of suspended coal-dust in fluxing and gradually cutting away the exposed surfaces of brickwork, is extraordinarily great, even superior to the disintegrating influence of extreme heat.

Hence a great claim to economy of the Siemens Regenerative Gas Furnace ; and Mr. Siemens affirms that the heat at which a suitably designed furnace can be worked is limited in practice only by the difficulty of finding a material sufficiently refractory of which it can be built.

Regularity of Shape requires that the brick's opposite sides should be truly parallel planes (excepting, of course, the special case where key hollows are left), and then arises sharp right-angled edges. The necessity for this requirement is obvious. In all forms of brickwork regularly moulded bricks produce even joints, prevent settlements, and effect economy as well as stability in the work. But in fire-brickwork, especially, an uniform shape of each individual component of the furnace permits, under extreme changes of temperature, an uniform expansion or contraction in all directions ; it tends to preserve the relative proportions, and thus to insure the general stability of the entire mass of the brickwork.

Uniformity of Composition. The brick on fracture, should present a compact uniform structure—not necessarily close, for indeed some maintain that a coarse grit of texture is the chief requisite, and that a coarse uniform structure, though pleasing to the eye, is not favorable to the refractory powers of a fire-brick, since the particles should have a facility for contraction or expansion under heat, and the air cavities act as valuable non-conductors of heat. But the brick should be free from stones, cracks, and irregular air-hollows ; and, on being struck, it should emit a clear ringing sound. The existence of this property usually involves that of the next.

Facility for cutting, i. e., a capability for being easily dressed with perfect accuracy, so that the brick shall not require a very violent blow, or split in a direction other than intended, or fall to pieces under a trowel. This property is an advantage in both building and repairs ; but that it is not of paramount importance may be inferred from the fact that the best fire-bricks ever used in the Manufacturing District least fulfil this condition ; yet no one, not even the bricklayers, whose tools suffer from the bricks' excessive hardness, would discontinue their use on this account. A fire-brick should never have its dressed surface, but only its "fire-skin" exposed to the furnace flame, for reasons similar to those against the exposure of the rubbed surface of an ordinary building brick to the weather. Hence it is to employ as many forms of differently moulded brick as possible, and the accompanying diagrams show the dimensions of the special shapes found most convenient in actual practice.

Though it is impossible to propound an exact rule as to the percentage of the cost of labor and materials in furnace-work, their relative proportions may be roughly said to average 33 to 67 in new work, and 60 to 40 in repairs, such as cutting out bridges, clearing the necks, slag-holes, etc.

Strength is obviously necessary to enable the bricks to avoid breakage in transport, and to withstand the pressure and cross strains to which it will be subjected when built into the work. It is stated by Rankine ("Manual of Civil Engineering," p. 367), that the resistance to crushing by a direct thrust—the bricks being set on edge in a hydraulic press—is per sq. in., in weak red bricks, from 550 lbs. to 800 lbs.; in strong red bricks, 1,100 lbs.; in fire-bricks, 1,700 lbs. But experiments recently made in the Royal Arsenal upon isolated cubes of 1½ in. side, cut from fire-brick "soaps" and placed between small squares of sheet lead, gave the following results:

		Cracking weight, lbs. per sq. in.	Crushing weight, lbs. per sq. in.
Stourbridge	A	1,478	2,400
Ditto	D	1,156	2,245
Newcastle	G	889	1,512
Plympton	Q	1,689	2,666
Dinas	U	1,123	1,288
Kilmarnock	W	2,134	3,378
Glenboig	X	1,067	1,556

and the average crushing weight of ordinary stock bricks was found to be from 666 lbs. to 866 lbs. per sq. in. Hence, all fire-bricks known may be said to have a strength far in excess of that which would be ever required of them in actual work.

Cheapness may appear an impolitic, and, therefore, unworthy consideration, but it practically determines the selection of 9-10ths of the fire-bricks used in this country.

For example, the freightage to London per ton (from 320 to 370 9-inch bricks) costs, on an average, 5s. 6d. from Newcastle, and 13s. from Stourbridge. Hence the great advantage possessed, *cœteris paribus*, by the manufacturers of the former place over those of the latter. And supposing the cost in London of one class of fire-bricks to be one-half that of another, and the above statement to be true, viz., that in the cost of new work, labor : materials, :: 33:67 it will readily be understood that, from a momentary point of view, it might be perfectly immaterial to the furnace owner whether he used the cheap or the dear fire-bricks—always supposing that the former be not so bad as to disintegrate and drop into the metal, and that a comparatively frequent "standing" of some furnaces in his establishment were of no great consequence to his pocket.

But, in point of fact, the *pros* and *cons* of this question are seldom so nicely balanced as in the hypothetical case I have assumed, and the invariable experience of the manufacturing district is that the best fire-bricks prove always to be ultimately the cheapest.

I now propose to attempt some general descriptions of the usual processes in vogue for making certain of the best known classes of English fire-bricks. In this manufacture more than ordinary care is found requisite to insure an uniformly regular success from its processes, and it should be observed that there is almost as slight a similarity between the modes of manufacturing fire and building bricks as there is analogy between their uses. With the former, use involves incessant repair, and after a few months' wear in a busy furnace, entire renewal; with the latter, even if of worthless quality, a builder, careless of reputation and indifferent to the possible discredit of distant failures, can often construct without fear of immediate detection.

Yet, even with this practical check upon quality, all experience in fire-bricks induces a certain wise toleration, so that isolated or exceptional cases of failure should not be allowed to justify the sweeping condemnation of an entire class.

In the following remarks care will be taken, for obvious reasons, to avoid identifying those makers who have courteously allowed the writer to inspect their works.

Yet the official recommendations of a certain agent's fire-lumps taken in company with the experience of some of the most eminent iron and steel firms in

Sheffield, may be allowed to sanction the opinion that a very high degree of excellence should be attached to the fire-clay manufactories of the Burton-on-Trent district. With these manufactories, therefore it is proposed to begin.

BURTON-ON-TRENT.

The clay is dug at a depth below the surface of about 20 ft. from open pits whose sides display the following strata :

		Thickness. ft.	in.
1.	A common earthy or brick clay (burns white)	6	0
2.	A kind of coal, locally termed "smut"	1	0
3.	A kind of marl, locally termed "clunch"	6	0
4.	A kind of coal, locally termed "smut"	0	6
5	Marl	6	0
6.	Fire-clay :—a bluish-black or slate-colored clay, of which the upper stratum 10 in. or 12 in. thick (locally termed "top black") is best	6	0
7.	A kind of coal, locally termed "smut"	1	0
8.	Bottle-clay, for sewage and drain pipes	9	0
9.	Iron-stone and "smut"	2	0
10.	Pot clay, for yellow ware	succeeds.	

The fire-clay is worked up into bricks as fast as it is obtained from the pits. It is not here customary, as in many districts, to "weather" the clay by long exposure before use, but it is sometimes moistened with water in order to lay the dust.

It is usually transported from the pits, and through the works, in trucks upon a tramway of 1 in. rails and 18 in. gauge; but the wire-rope overhead transport system is being generally substituted, and this will permit the easy transport of about a 4 cwt. load in each of the "trunks" or boxes upon an endless steel wire rope suspended from poles, passing over Fowler's clip drum pulleys, and worked by small portable steam engines.

The clay is pulverized in Carr's Disintegrator, composed of four cylindrical cages, 6 ft. 3 in., 5 ft. 7 in., 4 ft. 9 in., and 4 ft. 7 in. in diameter, arranged concentrically on wrought iron disc plates, so that the steel bars or beaters are about 4 in. apart, and 1 ft. 4 in. wide.

These sets of beaters revolve in opposite directions, by means of an open and crossing driving band working their disc axles, so that the first and third cases rotate in a direction contrary to that of the second and fourth; and they make about 200 revolutions a minute. The clay is lifted and delivered through a hopper into the interior of the machine (whose capacity is about 31 cubic ft.), by means of buckets upon a "Jacob's ladder" endless band, 10 in. wide. It is then driven through the mill, and ejected from it in a finely granulated state, by centrifugal force, at the rate of from 20 to 30 tons an hour. The clay is in this manner sufficiently pulverized to render a riddle unnecessary, if meant for fire-bricks ; but if for mortar or cement clay, it is passed through a wire mesh of 5 or 6 to the inch. The chief advantages of this machine over the ordinary "edge runner and pan" system of a mortar mill, consists in its ability to pulverize a moist, plastic clay as well as a dry clay, and in its power to disintegrate about 200 tons of clay per diem ; in which time the roller and edge runner process can, with the same steam power, grind only about 50 tons.

The bricks are fired in Hoffman and Licht's annular kilns, where, in successive chambers (each 15 ft. wide, 8 ft. 6 in. high, and holding about 20,000 bricks), different sets of bricks are dried, heated, burned, and cooled, by the currents of air feeding and escaping with the products of combustion from the same one fire. This form of kiln is found most economical in consequence of, *firstly*, the fuel being burnt with air already at an incandescent temperature ; and, *secondly*, the waste heat from both cooling and burning goods being entirely utilized in drying the new, fresh bricks about to be burnt, and raising them to a high temperature. The consumption of fuel in this form of kiln is, therefore, very small, in comparison with that in one of the ordinary form of construction ; and it is found that the burning of 1,000 bricks in the annular kiln requires only 2½ cwt. of Stavely dust coal, at 5s. 6d. a ton, instead of 20 or 25 cwt. of large "Grosby slack" coal at 7s. a ton.

The difference of cost for coal alone, therefore, amounts to about 8s. per 1,000 bricks, and the saving of labor is also very considerable. The bricks so fired are peculiarly well formed, and well burnt; the former, because they escape the additional handling and transport required by the dry-shed process ; the latter, because they are practically annealed by the gradual heating and gradual cooling in the successive processes of drying, heating, firing, and cooling, which extend over a period of about three weeks.

The Stourbridge fire clay district, including Amblecote, Brierly Hall, and the Lye, covers an area of from 8 to 9 square miles, with 6 fire-brick manufactories in Worcestershire, and 7 in Staffordshire.

From the pits on these works about 100,000 tons of fire-clay are annually raised, and the supply of fire-bricks has annually increased within the last 15 years from 14,000,000 to 30,000,000 per annum. In the neighborhood, the Quarry Bank Church is built entirely of Stourbridge fire-bricks; the Brockmoor Church is built partly of fire-bricks and partly of blue-bricks; and fire-bricks have been extensively used in the construction of the railway stations between Stourbridge and Birmingham.

The processes through which the clay passes during its manufacture into fire-bricks are 9 in number, viz.: digging, weathering, grinding, sifting, tempering, moulding, drying, and burning.

The Stourbridge fire-clay, or coal measure marl—a species of shale or slate-clay—is dug from pits (whose shafts are 6 ft. or 8 ft. in diameter, and steined) varying in depth from 120 ft. to 570 ft. It is generally found below 3 workable coal measures between marl or rock and an inferior clay. The former, overlying the fire-clay, is generally about 48 ft. thick. The fire-clay seam averages 3 ft. in thickness, never exceeding 5 ft., and thinning down to 5 or 6 in. when close to faults or small disturbances in the measures.

The middle stratum of the seam is always selected for the fire-clay, the top and bottom being thought too "strong." After being raised from the pits the fire-clay is picked over by women, who select the best lumps or "kernels" for glass-house pots, and reject for stains and mineral impurities. The pot clay is only found in small quantities—about sufficient for the glass manufactories—and costs on the spot 55s. per ton, whereas ordinary fire-clay costs on the spot only 10s. per ton; and 4 tons of clay (about 3½ cubic yards) are required to make 1,000 9-in. fire-bricks, whose local price is 50s.

Some of the glass-house pots recently made for one of the large plate-glass manufacturers at Ravenhead, weighed as much as 30 cwt. each when dry, and stood 6 ft. high.

The clay is exposed in spoil heaps over as large an area as can be secured, for from 3 to 18 months, according to the state of the weather. The action of frost, as with ordinary brick earth, is of great service in disintegrating the compact tough lumps of clay, and in dry weather the clay is frequently watered. In very wet weather a three months exposure will suffice for its proper "mellowing" or "ripening;" it ultimately slacks or falls to pieces. When new it is termed in the local phraseology "short and rough;" after due exposure it becomes "mild and tough." On some of the works the spoil heaps of clay contain over 10,000 tons, and it is estimated that 7 tons measure about 6 cubic yards.

After sufficient weathering, the clay is ground in a circular pan by 2 rollers or cylindrical stones, shod with iron rims 2½ in. thick, and weighing from 2½ to 3¼ tons a piece. They are driven by steam.

After being ground, the clay is carried on an endless band to a "riddle" of about 4 or 6 mesh to the inch for fire-bricks; 6 or 10 mesh to the inch for fine cement clay; 12 or 14 mesh to the inch for glass-house pot clay; the large-sized mesh being used for the sifting of the clay in wet weather. The large particles which will not pass through the "riddle" are carried back on an endless band to the pan and then re-ground.

As a general rule it is only for very large fire-brick lumps (such as blast furnace "tymps," 40 in. long, and 11 in. by 10 in.) that re-ground pots, crucibles, or bricks locally termed "grogg," are added to the clay before grinding; and fire cement clay is always ground pure.

After passing through the "riddle," the clay is tempered, or brought to a proper degree of plasticity by the addition of water.

It is then thoroughly stirred and kneaded in a circular cast-iron pug-mill by revolving knives projecting from a vertical shaft driven by steam power.

The clay is forced down by the obliquity of the rotating knives, and steams slowly from a hole near the bottom, whence, after being cut by wires into parallelopipedons, it travels on in an endless band to the moulding sheds.

The bricks are then moulded by hand in the usual manner, in moulds 10 in. by 5 in. by 3 in., or thereabouts, and dried at a temperature of 60 or 70 deg. in sheds 120 ft. long and 30 ft. wide, beneath whose floors run longitudinally two flues, heated by small furnaces. In fine weather, however, the sun's heat is made to economize fuel.

The bricks are burnt in circular-domed kilns, or cupolas, locally termed "ovens," where they remain from 8 to 14 days, being fired with the real intensity of flame, or white heat, for about 4 days and 3 nights ; they usually require 7 days to cool down. The fire is slowly increased, and gradually lowered ; the time of burning is regulated by a kiln man in charge, who inspects the baking bricks from time to time through holes in the domed roof of the "oven." A chimney stack is on the outside of the kiln, and the flame burns with a down draught descending through holes in the floor, the fire-holes being merely openings left in the thickness of the wall of the kiln, and protected from the wind by buttresses long enough to allow room for the firemen to attend the fires. The coal is, of course, obtained from the pits which provide the clay. Most of the kilns hold each 12,000 bricks, but some are made large enough to contain each 30,000 or 35,000 bricks, the capacity of a kiln being roughly calculated upon the assumption that 10 bricks require 1 cubic ft. of space in the kiln.

For conveyance of the clay and bricks about the Stourbridge works, little trucks called "skips" are employed in the pits, and throughout the brick-fields. Their platforms, standing 1 ft. high, are 4 ft. square, and consist of $1\frac{1}{2}$ in. planks. Their wheels, of cast iron, are 10 in. in diameter, with 2 in. axles. The rails, 2 ft. apart, consist of $\frac{1}{4}$ in. wrought-iron angle rails, 3 in. wide, and $1\frac{1}{2}$ in. high.

The mode of fire-brick manufacture in the Newcastle district differs from that of Stourbridge in a very few and unimportant particulars.

The clay, in a spoil heap of 30,000 tons, is often exposed for 7 or 8 years, during which time it is picked over by boys, who remove pyritous fragments exposed on disintegration.

When required for fire-bricks, it is ground by cylindrical edge-stones, weighing 3 tons each, in a revolving pan, or else upon the ground, and then passed through a wire "riddle" of 6 or 8 mesh to the inch.

Throughout the works are 18 in. tramways, and pony trucks convey the materials from place to place. After tempering, moulding, pugging, and drying, the bricks are burnt in kilns about 15 ft. by 14 ft., by 10 ft. high, holding each 15,000 bricks.

They are fired for eight or nine days, during which time 5 tons of coals are consumed. The flame and hot air pass from a fire-box at one end of the kiln to outlet flues at the other end of it, and thence into an external chimney.

About 80,000,000 of fire-bricks are produced annually from the Newcastle district. *i. e.*, nearly three times the annual supply of the Stourbridge works.

Very excellent fire-bricks are made from the refuse of *Kaolin* or china clay, found in Cornwall and Devonshire.

Kaolin is produced by the disintegration of "pegmatite," or felspathic granite, under the action of the carbonic acid and moisture of the atmosphere; it then becomes basic silicate of alumina. The kaolinitic fire-bricks, containing very little iron or lime, possess extremely refractory powers, and have, in fact, been found in the Royal Arsenal air furnaces to be equal or superior in this respect to any other known fire-bricks in the kingdom.

With their rivals they compare as favorably for economy as for endurance; but the former is, of course, a specially local advantage, which might possibly disappear in another district.

Kaolinitic fire-bricks enjoy, however, a very high reputation in lead-smelting furnaces, converting vessels of the Bessemer steel process, the retort furnaces of gas works, kilns for burning iron pyrites, etc., etc. For the moderate heat to be withstood by ordinary boiler seatings, a burnt compound of kaolin, sand, and local clay, in equal parts, is found to be as good as the fire-lumps ordinarily employed.

The refractory powers of clay will, of course, by the addition of pure silicious sand, which can be produced by grinding sandstone if it is not obtainable in a state of nature.

The Dinas fire-brick is well worthy of attentive consideration, if, indeed, solely for the reason that it is, in the opinion of Mr. C. W. Siemens, F. R. S., the "only material of those practically available on a large scale, that I have found to resist the intense heat at which steel-melting furnaces are worked." Now the average heat of a steel-melting furnace, measured by electrical resistance, may be accepted as 2,200 deg. Centigrade (=3,992 Fahrenheit), and that of the ordinary air-furnace, at welding heat, as the former, the Dinas brick, will last, it is found, for four or five weeks, though their thickness will, in that time, have been reduced from 9 to 2 in. But these extraordinary results, it should be remembered, have been only obtained in the Siemens Regenerative Gas Furnace, wherein, the flame being quite pure and free from the suspended dust which is usually borne from the fuel by the keen draught of air through an ordinary reverberatory furnace, the brickwork is not fluxed on its surface, and gradually cut away thereby, but it fails, if at all, from a general softening and fusion throughout the entire mass. For the ordinary puddling mill or air furnaces, the Dinas bricks, notwithstanding their ability to resist very high temperatures, are somewhat troublesome in actual practice. They are very friable, porous (and thus imbibe moisture freely), they swell extremely with heat, and do not contract to their original dimensions.

If allowed to cool down (and it is customary to let the furnaces "stand," in most works, from mid-day on Saturday till mid-day on Monday) they are apt to crack, flake in fragments, and then fly to pieces in consequence of the decrepitation of portions of the quartz composing them. From their extreme tenderness they are unlikely to prove durable if applied in portions of furnaces where they would be subjected to much mechanical wear.

Yet their refractory powers are remarkably great, and they bear a very high reputation with many owners of copper-smelting, iron, glass, gas-works, coke ovens, etc., and they seem to be highly esteemed for the arches of reverberatory furnaces in the copper works of Swansea, at Middlesborough, and at Ebbw Vale.

The tabulated analyses show the high percentage of silica which these bricks contain; and from their silicious nature it is obvious that they should not be exposed to the action of slags rich in metallic oxides, or to the fumes from lead ores, or to proximity with alkaline substances generally.

IRON ELECTROTYPE.

From "Engineering."

The art of electrotyping, which owes its discovery almost to accident in the year 1839, has since that time grown into a very extensive branch of manufacture. The discovery of this most useful art was made almost simultaneously in England and in Russia. In England Mr. Thomas Spencer and in Russia Professor Jacobi have to be individually credited with the invention, which has since been developed and brought to the degree of perfection in which we now find it in daily practice. So far the reproduction of engraved plates, medallions, and objects of art has only been effected in the softer metals, such as gold, silver, and copper, although attempts were long since made to reproduce them in iron. Few persons probably were aware, however, that this important object had been accomplished, until, like ourselves, they saw a case containing some beautiful specimens of iron electrotype in one of the corridors of the late International Exhibition at South Kensington. The specimens were placed there about 3 months before the close of the Exhibition, and were exhibited by Messrs. Bryan, Donkin and Co., of Bermondsey, as agents for the inventor. These specimens consisted of bank-note and various other plates, medals, medallions, and a page of printing type electrotyped in iron. This new process has been perfected by M. Eugène Klein, who is at the head of the chemical department of the Imperial State paper manufactory in St. Petersburg. Many difficulties have arisen and have been successfully surmounted in developing this process to its practical issue. Attempts were made to effect the object so far back as the year 1846, but which were unsuccessful, and it was about 20 years before the problem was definitely solved. The importance and reality of the progress, however, are now unquestionable, and an extended knowledge of the process must inevitably lead to its general adoption. At the present time we believe its application is confined to the Russian Imperial State paper works, where it has been in active operation for the past three years, the iron plates replacing those of copper for bank-note printing and for other similar purposes. The application of the invention, however, extends to all the other branches of the art of electrotyping as demonstrated by the specimens to which we have already referred.

From a paper upon the present subject, read by Professor Jacobi before the Academy of Sciences in Russia, in 1868, it appears that in the previous year M. Feuquières sent to the Paris Exhibition some specimens of iron electrotype which presented a fair appearance as regarded surface, but still were inferior to those produced by M. Klein in the year following. M. Feuquières does not appear to have published the process by which he obtained his results, and he, moreover, only spoke of it with the greatest reserve. Professor Jacobi, however, states on the authority of Professor Varrentrapp, of Brunswick, that the process and the bath employed differ essentially from those of M. Klein, whose results may be considered as being perfectly independent.

Referring to the process of electrotyping in iron, Professor Jacobi observes that the good quality of the iron deposit depends principally upon the greater solubility of the anode. The augmentation of its surface not having produced the desired effect, M. Klein conceived the idea of combining the anode of iron with another of copper. The Professor varied this combination by replacing the copper with horn charcoal, which gave more powerful results. The effects of this combination were thus rendered complete, the metal negative combined with the iron in the same bath formed a duplicate layer, which worked as a cathode opposite the iron, and as an anode by its combination with the copper wire, or the positive pole of the pile, which furnished the principal current. The surface of this electrode consequently disengaged hydrogen and oxygen simultaneously, which combined in proportions which form water. The surplus hydrogen freely disengaged itself, or produced a polarization of the electrotype. If, observes the Professor, the oxygen is most abundant, and if the electrotype consisted of an inoxidable substance, such as horn charcoal, it would also have disengaged gas, and have given a feeble polarization. If, however, the electrotype is oxidable like copper, it will be oxidized and dissolved. By immersing a galvanometer in the circuit, Professor Jacobi has observed the deviation of the needle diminish by degrees, whilst the current was very feeble, and it became perfectly still after the force of the current had been increased to a certain degree. At length, passing that degree, the Professor noted that the deviation again became inconstant. By means of the galvonometer, it therefore becomes easy to so regulate the current as to disengage neither the oxygen nor the hydrogen from the cathode.

So far, Professor Jacobi. Turning now to a letter from M. Klein, which was placed before the Russian Academy of Sciences in 1868, we have recorded the methods employed by him in the production of iron electrotype. M. Klein saw M. Feuquières' specimens at the Paris Exhibition, and, encouraged by Professor Jacobi, he, on his return to St. Petersburg in October, 1867, renewed his attempts to electrotype in iron. The scientific interest which attached to the new development, and the eminently useful applications of which he saw it was susceptible, especially in the departments of engraving and printing, stimulated M. Klein, and in the early part of 1868 he had accomplished his object. The medals produced in the early part of M. Klein's researches, showed on their reverse, porosities and deep hollows which penetrated nearly through the thickness of the deposit. These cavities were also observable in great numbers in the productions of M. Feuquières. In M. Klein's later specimens these singular cavities—which probably proceeded from bubbles of gas—entirely disappeared, and their reverses are in no way inferior to those of copper specimens produced under the best conditions. The starting point of M. Klein was the steeling of engraved copper-plates, which process was effected in a bath composed of the chlorates of ammonia and iron, to which he added a small proportion of glycerine. Those, however, who have paid attention to this steeling process have had occasion to remark that in giving the deposit of iron a greater thickness, the surface cracked, and the deposit detached itself from the cathode in excessively brittle flakes. It became necessary, therefore, to employ baths of two different classes, composed of sulphate of iron and sulphate or chlorate of ammonia. Finally, M. Klein devised three baths after the formulæ $Fe\ O, S\ O_3 + N\ H_4\ O, S\ O_3 + 6\ H\ O$.

The first bath consists of a concentrated solution of crystals of double salt $Fe\ O, S\ O_3 + N\ H_4\ O, S\ O_3 + 6\ H\ O$ above mentioned. The second bath was composed by mixing the concentrated solution of each of these two salts in the proportions of their equivalents. At length M. Klein obtained the third bath by taking a solution of sulphate of iron, precipitating the iron by carbonate of ammonia and dissolving the precipitate by sulphuric acid, getting rid of all excess of acid. In preparing the baths of the second class, M. Klein, as we have stated, mixed the solutions of chlorate of ammonia and sulphate of iron in the proportions of their equivalents. Another method employed is, to dissolve in a solution of sulphate of iron as much chlorate of ammonia as it will readily absorb at a temperature of about 66 deg. Fahr. All these baths were concentrated as highly as they could be. As an anode, M. Klein employed iron plates giving a surface of about eight times that of the copper cathode. In using a Daniell battery for the decomposition the deposit was formed in 24 hours upon the whole of the cathode. The deposit, however, was full of flaws, and was easily detached and broken up into fragments.

As it often happens that the solution of sulphate of copper improves by use, M. Klein hoped that the iron solutions would act in a similar manner. He therefore continued the experiments for several days without, however, obtaining any better results. Under the advice of Professor Jacobi, instead of a pair of Daniell cells for each of the five stages of decomposition, he then employed four pairs of feebler Meidinger cells, uniting them in series with the five stages of decomposition. This arrangement was found to give a smaller development of hydrogen at the cathodes and better final results. The deposits, however, were not yet perfect, some exhibiting porosity and others being furrowed.

Conceiving from previous experience that this was due to acidification of the bath, M. Klein tested it, and found a very decided acid reaction. He attributed this acidification to the circumstance that the quantity of iron deposited on the cathode was greater than that dissolved by the anode. It was therefore necessary to give the anode a greater degree of solubility, and as that could only be effected by increasing its area, M. Klein conceived the idea of placing in the bath a plate of copper and uniting it with the iron. The result of this combination was very remarkable; not only were the baths of the first class rendered neutral after several hours, but the deposits became much more uniform. Their color was a dull grey; they adhered perfectly to the cathode without warping or cracking in any part. During the first 24 hours the surfaces remained perfectly even, but afterwards they began to exhibit minute cavities similar to the appearances often produced upon galvanic deposits of copper. These cavities, however, rarely penetrated to the depth of the deposit. Their production is attributed to the superabundant disengagement of gas on the surface of the cathode. It probably happens that these bubbles attach themselves strongly enough to hinder the formation of the deposit. If the energy of the current becomes too great, these annoying phenomena are produced more frequently. By reducing this energy in the process, and having only an imperceptible disengagement of gas by diminishing the concentration of the bath, or augmenting the resistance of the solid portions of the circuit, the formation of these cavities entirely disappeared, and the beautiful results to which we have already referred have been obtained. A microscopical examination of the reverses of the deposits produced by M. Klein's final process fails to discover any porosity or irregularity in the specimens.

On leaving the bath the iron is as hard as tempered steel and very brittle. Reheated to a dull red heat it loses much of its sharpness and hardness. Heated to a cherry red it becomes malleable, and may be engraved as easily as soft steel. If the deposits are produced in good condition, and annealed uniformly and with the necessary precautions, they are neither subject to warp nor bend. There is no contraction, but on the contrary, a slight degree of expansion, almost imperceptible, however. Owing to the necessity of having bank-note and similar plates identical in every respect, it is of the first importance that they should not be distorted nor have their dimensions altered in the process of annealing. It appears that the galvanic deposit of iron has not only permanent magnetism, but that, like soft iron, it receives the magnetism of position.

We have now received both the failures and the successes of M. Klein. Of the importance of the practical application of the process, there can be no doubt whatever. By replacing plates of copper by those of iron, greater facilities will be afforded for producing publications, works of art, and especially bank-notes and checks. Iron electrotype plates are found to be almost indestructible. They not only can be printed from an almost unlimited number of times, but they are better calculated than those of copper to withstand those inevitable accidents constantly occurring in printing establishments. Printers are sometimes obliged to set aside as useless their best plates, which are often damaged by a grain of sand, or by a chance knot in the paper. These accidents not only involve the expense of renewing the plates, but sometimes occasion interruptions and delays in works of a very pressing nature. These are some amongst the many which may be expected to accrue from the introduction of iron electrotype.

IRRIGATION v. DISINFECTANTS.

From "The Engineer."

Ever since the commencement of the sewage difficulty, the rival claims of the irrigation and disinfectant partisans have been prominently placed before the public; yet the problem is still unsolved. The results of irrigation are tangible and appreciable; so also, it is said, are those of the deodorizing and disinfecting systems. Our own opinion on the respective advantages of the two are too well known to require any recapitulation on our part. The whole subject is now on its trial, and until the experiment which is being conducted with regard to the sewage of the metropolis is a success or a failure, all criticism may be fairly suspended. The task which the Native Guano Company have undertaken to accomplish at Crossness differs in no respect from that which has always constituted hitherto the insuperable obstacle to a satisfactory solution of the important question. It is not intrinsically of an arduous character. It involves only two conditions. The one is the purification of the effluent water; the other the utilization of the solid residue. Both of these must, however, have a reference to some standard. The former ought to attain to that prescribed by the Commissioners appointed to inquire into the pollution of rivers. Perhaps this is of a rather stringent character. One thing is nearly certain, viz., if the Conservators of the Thames elect to adhere to this standard, there will be an end to the experiment to which we have alluded. There is no difficulty in purifying the metropolitan sewage to an extent which will allow the effluent water to pass into the river in a state of almost absolute purity compared to the filth which is at present pumped into it. It remains to be seen if the Board of Conservancy will be content with an amelioration instead of a cure of the evil. That the result of the forthcoming experiment will very materially improve the present condition of the sewage discharged into the Thames, we have not the slightest doubt. That it will not purify the effluent water so as to bring it up to the standard of the Rivers' Pollution Commissioners, we have also not the slightest doubt. But between this standard and that which will probably satisfy the Conservators there is, fortunately for the experimentalists, a wide margin. So far as the pollution of the Thames is concerned by metropolitan sewage, the term applied to its guardians is a complete misnomer. They are able to hold their own with the small fry, but when they have to tackle a big fish, such as the Metropolitan Board of Works, they are nowhere. They give no mercy to the riparian small towns and villages situated beyond the municipal boundary, and yet allow the whole sewage of the metropolis to be discharged into the river they are presumed to conserve.

It may be assumed that with respect to the Thames the first condition of the sewage question may be considered to be partially fulfilled. In other words, the effluent water which will be subsequently discharged into the river from the new works in course of erection at Crossness, will be comparatively so pure with respect to that which has hitherto been pumped into the stream, that it will be considered to leave nothing to be desired. The proof of its actual purity will be the analysis of it, which there is no doubt will be undertaken by competent authorities. There now remains the second part of the question to be taken into consideration. It involves the manufacture of the salable manure, and collaterally the cost of its production. It is this part of the plan that is to pay for the whole operation, and recoup the shareholders for the money they have expended. There are a great variety of opinions respecting the manure made from the solid residue of the purified effluent sewage water. It is asserted that it commands a high price in the market, and is eagerly sought for by agriculturists, while some maintain that it will barely pay the expenses of cartage. It should be borne in mind that the mere fact of a manure rich in manurial ingredients being manufactured from sewage residue, is no test of the financial success of the process by which it is produced. Nothing is easier than to make a rich and valuable solid manure. All that is required is to put the necessary ingredients in, and the thing is done. Nothing more is necessary than to combine the manurial elements with the actual sewage residue, and then say there is a valuable solid manure manufactured from sewage. But really to effect the object in view in such a manner as will pay the cost of manufacture is to prepare the manure from the sewage, and from the sewage alone. It is here that the uncertainty prevails. What proportion of the manurial value of the solid material is due to the sewage, and what to the ingredients purposely combined with it, the value of which latter is previously well known? Chemists and analysts can ascertain the composition of a manure, and from that assign its theoretical agricultural value. But the farmer is the person who really determines the practical, that is, the profitable value of the manure, and on this point chemists and farmers differ very widely. If the material prepared in the manner described derives its value, not from the sewage, but from certain ingredients mixed with it, the utility of which is recognized by all, the farmer may as well purchase those ingredients in some other shape. There is obviously no gain in buying a lot of dirt to act merely as the vehicle for a comparatively small quantity of genuine manure.

We, as well as everyone else, are waiting with much interest the result of the trial at Crossness, for there is not the slightest doubt that, omitting all consideration of the irrigation system of utilization of sewage, the general question very much depends upon the success or failure of the operations which are to be carried out there. With the exception of the A. B. C. scheme, all the others of a similar nature, having the same end in view, have, from one cause or another, gradually fallen through. That one alone, notwithstanding the vigorous and perhaps rather severe condemnation passed on it by the Rivers' Pollution Commissioners, has kept its head above water, and attempted a solution of the great problem on a scale of magnitude commensurate with its importance. Indeed, to judge from the market price of the shares of the Company, it ought to be the most profitable investment open to capitalists. Our own views on the subject of the utilization of sewage have been so often expressed that we need not recapitulate them. While still adhering to those opinions, and believing that the irrigation principle is the best, we should nevertheless be rejoiced to witness the success of the experiment at Crossness. But the trial must be complete in every sense. It will not be sufficient to establish that a portion of the metropolitan sewage can be treated successfully for a brief period. It must be demonstrated that the method is capable of dealing with any quantity for any length of time continuously. Were the system once in active operation, a breakdown would be an event of the gravest moment. The flow of sewage is incessant day and night, and the means for providing for its treatment must be also always available. This is a difficulty not to be despised, even when it is confined to small towns, but it becomes very formidable when it assumes the proportions resulting from its connection with a city of the size and population of the metropolis.

STRAINS IN STRAIGHT GIRDERS AND TRUSSES.

By E. SHERMAN GOULD, C. E.

I.—STRAIGHT BEAMS AND GIRDERS.

A. *Horizontal Strains.*

Let us consider the effect of a weight placed upon the centre of a beam, resting on two supports.

It is evident that each support sustains one-half of the weight. The principle of reaction permits us to consider the beam as being pressed upward at each end with a force equal to the pressure on the supports, against the weight at the centre, considered as a common fulcrum.

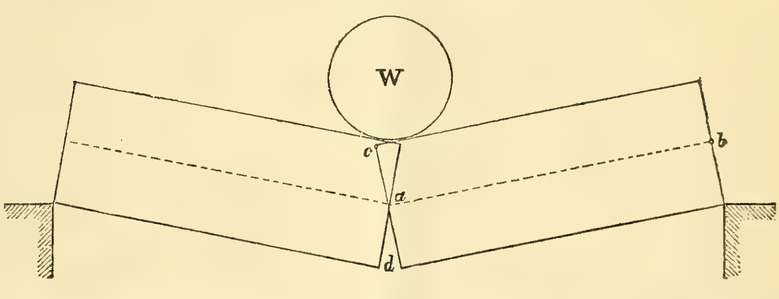
This force acts with a leverage equal to half the length of the beam, and tends to crush the beam together at the top and tear it asunder at the bottom. Calling the weight at the centre W, and the length of the beam L, the strain tending to fracture the beam may be written

$$\frac{W}{2} \times \frac{L}{2} = \frac{W L}{4}*$$

This is the strain tending to produce rupture at the centre. It is constant for a given weight and length of beam, irrespective of the shape or material of the beam. It is resisted at the centre by the strength of the material of the beam, multiplied by its depth at the centre.

This must be further elucidated. We have seen that the weight tends to compress the top of the beam and extend the bottom. It is clear that there must be some point in the strained section where the character of the stress changes, that is, where it ceases to be compressive and becomes tensile, and *vice versa.* This point is assumed, in a straight beam, to be at the centre of its depth. Around this point, under the influence of the weight, the beam tends to turn with a force equal to $\frac{W L}{4}$. Thus

Fig. 1.



To this crushing and extending force the material of the beam opposes a certain resistance, which is the more effective as the depth of the beam, and therefore the leverage with which it acts, is greater. In effect, the system of strains and resistances, as shown above, constitutes two bent levers. The force $\frac{W}{2}$ acting with the leverage *a b*, tends to turn the beam around the point *a*, while the resistance of the material of the beam to compression and extension, acting with the respective equal leverages *a d* and *a c* tend to keep it in a straight line. It was early seen in the study of the resistance of materials, that the material in the top and bottom edges of a beam was rendered the most effective from the greater leverage with which it acted, and the effort to concentrate most of the material at those points, led to the introduction of girders formed with top and bottom flanges, joined by a web. As certain materials resist one kind of strain better than they do the other, the scantling of the flanges is proportioned with a view to establishing an equality of resistance at top and bottom.

Thus we have a force $\frac{W L}{4}$ tending to turn half the beam, around the point *a*, resisted by a certain factor R (the resistance of the material to compression) mul-

* It is of course unnecessary to explain that it is only the moment of the reaction of one support which tends to produce rupture. Should the student have any difficulty in realizing this, he need only recall the effect produced by two men of equal strength pulling against each other, on a rope. Though both pull, there is no more strain on the rope than if one end were made fast and only one man were pulling upon it.

tiplied by $a\,c$, *plus* a factor R' (the resistance of the material to extension) multiplied by $a\,d$. But the girder is, as we have seen, so constructed that R=R', the resistance of the girder is therefore R $(a\,c+a\,d)$. But $a\,c+a\,d$=D, or the depth of the girder at the centre. We have then, for the resistance of the girder at the centre,

R D.

In order that the girder may sustain the weight, it is necessary that this force be at least equal to that tending to produce rupture. That is, we must have

$$R\,D=\frac{W\,L}{4}.$$

From which we obtain

$$R=\frac{W\,L}{4\,D}.$$

Example.—What is the value of R for a wrought-iron girder, 1 ft. deep from centre to centre of flanges, resting on two supports 12 ft. apart, and bearing a weight of 12 tons, placed at the centre?

Here

$$R=\frac{12\times 12}{4\times 1}=36 \text{ tons.}$$

Taking the safe resisting strength of wrought iron to crushing and tearing* at 5 tons per sq. in., the flanges of the above girder must have a section of 7.2 sq. in.

The above formula gives the strain at the centre of the girder. To obtain the strain at any other point, we must substitute the distance from that point to the nearest abutment, for $\frac{L}{2}$ in the formula. That is the strain at any point in the flanges of a girder supported at both ends and loaded in the middle, is equal to the reaction of the supports multiplied by the distance of the given point to the nearest support. If in the above example we wished to find the value of R for a point half way between the centre and one of the supports, we should put

$$R=\frac{12\times 3}{2}=18 \text{ tons.}$$

If the load be applied at a point other than the centre, the weight borne by either support is to the whole weight as the distance from its point of application to the other support is to the whole length of the girder. Thus, in our example, if W be placed half way between the centre and the right support, the weight sustained by that support is $\frac{3}{4}$ W = 9 tons, and the weight sustained by the left support is $\frac{1}{4}$ W = 3 tons, the sum of the two making up the whole load. The moments of the reactions of the supports around the point of application of the load are equal. Thus in the above, $\frac{3}{4}\,W\times\frac{1}{4}\,L=\frac{1}{4}\,W\times\frac{3}{4}\,L$. The strain at this point is therefore given by either side of the above equation.

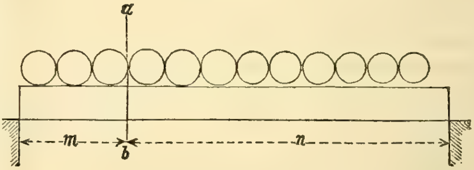
The strain at any other point is equal to the moment of the reaction of the support between which and the applied weight the given point is located, around such point. This is an extension of the rule enunciated in reference to a central weight. If, in our example, W be placed 3 ft. from the right support, the value of R for a point 3 ft. from the left support is

$$\frac{W}{4}\times\frac{L}{4}=9 \text{ tons.}$$

It will be seen in all cases of a single weight, that the maximum strain occurs at the point of application of the weight.

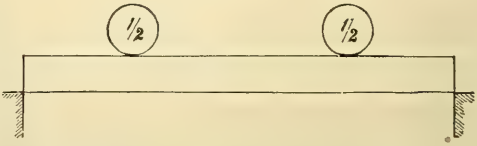
Let us now consider the case of a girder supported as before, but over which the weight is evenly distributed.

Fig. 2.



As far as the pressure on the supports and the strain on the flanges at the centre are concerned, we might consider the weights as being concentrated in equal groups about the centres of gravity of the two halves of the girders, thus:

Fig. 3.



Each support bears half the weight, that is the right support bears $\frac{3}{4}$ of the right half weight and $\frac{1}{4}$ of the left half weight, making $\frac{W}{2}$ in all, and the same

* Though the resistance of wrought iron to a tensile strain is considerably greater than its resistance to compression, it is found in practice, particularly with riveted flanges, that it is not safe to use a smaller section at the bottom than at the top.

reasoning applies to the left support. The strain at the centre is obtained by calculating the separate action at that point of each half weight, and taking their sum. Thus, the reaction of the right support from the left half weight being $\frac{1}{4}$ of $\frac{W}{2}$, the strain which that half weight exerted at the centre is $\frac{W}{8} \times \frac{L}{2} = \frac{W L}{16}$. The other half weight exercises an equal strain at the same point, and the sum of these gives a total strain of $\frac{W L}{8}$. We have therefore, in the case of a girder so loaded, $R = \frac{W L}{8 D}$ for the central strain, which is half that produced by an equal weight concentrated at the centre.

By taking the strain at other points between the two weights, we find it equal throughout the central segment.* This fact precludes the using of this transformation of the weights in determining the strain at various points in a girder uniformly loaded. It is always possible, however, to ascertain the strain at any given point in a girder so loaded, by supposing the weights grouped at the centres of gravity of the segments into which such point divides the girder. Thus, to determine the strain at a point distant m from the left support (Fig. 2), we might consider the weights on each side of $a\ b$ as concentrated at the centres of gravity of their respective segments, viz.: the weights on m concentrated at $\frac{m}{2}$ and those on n at $\frac{n}{2}$. Reasoning as for the strain at the centre, we should find the strain at $a\ b$ due to the weights on

$$m = \frac{m\ W}{L} \times \frac{m}{2\ L} \times n = \frac{W\ m^2\ n}{2\ L^2},$$

and that due to the weights on

$$n = \frac{W\ n^2\ m}{2\ L^2}.$$

Adding, we have,

$$\frac{W}{2\ L^2}\ (m^2\ n + n^2\ m)$$

for the actual strain at $a\ b$.

But this method of reasoning leads, as we see, to a rather complicated formula. It is better to treat the question in the following manner: We have, as in the case of the girder loaded at the centre, the reaction $\frac{W}{2}$ of the right support acting upward with the leverage n. In the present case however, we have a certain amount of resistance to this strain, due to the distributed load upon n, and independent of the resistance of the girder itself. That is to say, the loaded segment n acts against the upward force $\frac{W . n}{2}$ to the extent of the moment of the weight upon its centre of gravity around the given point. The weight on n is $\frac{n}{L}$ ths of W. The strain and resistance at $a\ b$ are therefore expressed by the equation

$$R\ D = \frac{W\ n}{2} - \frac{W\ n}{L} \times \frac{n}{2},$$

whence

$$R = \frac{W}{2\ D}\ \frac{(n - n^2)}{L} = \frac{W}{2\ D\ L}(L\ x - x^2)$$

In the last expression x has been substituted for n, as either of the segments m and n gives the same result.

If the above equation be resolved for the value of D, and R be made constant, the successive values, D, will vary as the ordinates of a parabola.

The previous problems, where the strain at any point is ascertained by the reaction of that support between which and the weight the given point is located, may also be resolved, though not so readily, by taking the moment of the reaction of the other support, less the moment of the loaded segment, as in the present case.

The maximum strain, when a girder is uniformly loaded, is at the centre. When the girder is loaded with a single concentrated weight, the maximum strain is at the point of application of such weight. If now a girder be at the same time subjected to an equally distributed load, and a single weight placed at some point other than the centre, the position of the point of greatest strain as determined by either one of these loads considered separately, will evidently be modified by the action of the other. The maximum strain in the flanges of a girder, however loaded, occurs at the point which forms the centre of equal moments of the reactions of the two supports. Therefore, to obtain the point of greatest strain in a

* We may therefore obtain the strain throughout that portion of a girder comprised between two equal and symmetrically placed weights, by taking the moment of the reaction of one of the supports around the point of application of the weight nearest to it.

girder bearing two loads, one uniformly distributed and the other concentrated at a single point, we must find the total reaction of each support from both weights, and then determine that point in the girder around which the moments of the same shall be equal.

Suppose, for example, a beam loaded with the equally distributed load W, and also with a single weight equal to W placed midway between the centre and the left support. The reaction of the left support is $\frac{W}{2}$ from the distributed, and $\frac{3}{4}$ W from the undistributed load. Total reaction of left support $\frac{5}{4}$ W. The total reaction of the right support is found to be $\frac{3}{4}$ W. Let L represent the length of the beam and x the distance of the centre of equal moments from the left support. Then $\frac{5}{4}\,W\,x = \frac{3}{4}\,W\,(L - x)$; whence $x = \frac{3}{8}\,L$.

B. *Vertical Strains.*

So far we have considered only the strains in the upper and lower edges or flanges of a beam or girder, and in the case of a solid beam, these horizontal strains, as they are called, are the only ones of which it is necessary to take account. But when a girder is formed of flanges joined by a comparatively light web, it becomes necessary to ascertain the vertical or shearing strain, that is, the strain which the web must sustain in keeping the two flanges apart, in order to proportion the scantling of its parts to the duty it may be called upon to perform.

These strains are entirely independent of leverage. In the case of a single weight applied to the top of a girder, the tendency is to crush the web with a force equal to the reaction of the supports. Thus, if the weight be applied at the centre, the shearing strain throughout the whole girder is $\frac{W}{2}$. If it be applied midway between the centre and one of the supports, the shear on all parts of the web between it and that support is $\frac{3}{4}$ W, and on all parts between it and the other support, $\frac{1}{4}$ W.

When the girder is uniformly loaded, the case is different. If we consider a girder loaded with 12 equal weights (Fig. 2), it is obvious that the web at the ends of the girder must be strong enough to sustain the whole 12 weights—6 on each end. At the points between the 1st and 2d, and the 11th and 12th weights, it need be only strong enough to sustain the 10 intermediate weights, and so on to the centre, where the shearing strain is *nil.* Therefore, in a girder uniformly loaded, the shearing strain at any point is equal to the weight on that part of the girder comprised between the centre and the given point, and this strain is the same at the corresponding point on the other side of the centre. We see by this that the point of maximum horizontal strain corresponds to that of minimum vertical strain, and *vice versa.*

There is a curious phenomenon connected with the shearing strain of an equally, as compared with that of a partially loaded girder. One would suppose that the greatest strain of this nature at any section, $a\,b$ (Fig. 2), would occur when the whole girder was loaded throughout. But such is not the case. If the 3 weights to the left of $a\,b$ be removed, the shear at $a\,b$ will be augmented. To investigate this phenomenon, let L represent the whole length of the girder; w the weight per unit of length (that is the weight per foot, yard, or whatever unit is used in L); n the segment of L bearing the load; m the unloaded segment. Referring to Fig. 2, to get the shearing strain at $a\,b$ when the 3 weights on m are removed, we may suppose those on n concentrated at its centre of gravity, and calculate the weight sent by them in this position to the left support, which will be the shearing strain at $a\,b$ and throughout the unloaded segment.

The centre of gravity of n is $\frac{n}{2}$, and the weight on n is n W. Accordingly, the weight carried by the left support, would be the half of $\frac{n}{L}$ ths of n W, or $\frac{n^2\,W}{2\,L}$, which would be the shearing strain sought for. If now we replace the 3 weights on m, so that the girder becomes entirely covered. We find the shearing strain at $a\,b$ to be

$$W\frac{(m+n-m)}{2} \text{ or } W\frac{(n-m)}{2}.$$

Subtracting this from the strain at the same point when the girder is partially loaded, we have

$$\frac{n^2\,W}{2\,L} - W\frac{(n-m)}{2} = \frac{W}{2\,L}\,(n^2 - L\,n + L\,m).$$

But $n^2 - L\,n + L\,m = m^2$, so the excess of strain at any point of a girder when only the longer of the two segments into which it divides the girder is loaded, over the strain at the same point when both segments are loaded $= \frac{W\,m^2}{2\,L}$.

It seems a little difficult to realize that a strain is actually augmented by a reduction of weight, and if experiment were not at hand to verify theory in this matter, one could hardly accept the fact.

For a further discussion of this point, see Stoney on Strains, Vol I., p. 30.

II.—STRAINS IN STRAIGHT TRUSSES.

We have now considered the strains produced in a beam or girder supported at both ends, under all the circumstances of loading which can ordinarily occur. We will proceed to investigate the effect of these strains in bridge construction.

A bridge truss may be considered as a large girder, and when the web is formed of plates or riveted latticing, the strain at any given point is ascertained by the direct use of the formulas already given. When, however, the web is formed by trussing, the varied disposition of the different members constituting the truss, renders the calculation more complicated; for in determining the strain upon any member of the web or truss, it is necessary to ascertain precisely what amount of the weight is sustained by that member, and in finding this strain for any given point, it is often necessary to take some other point, more or less distant from the one actually in question, as that which determines the loaded segments.

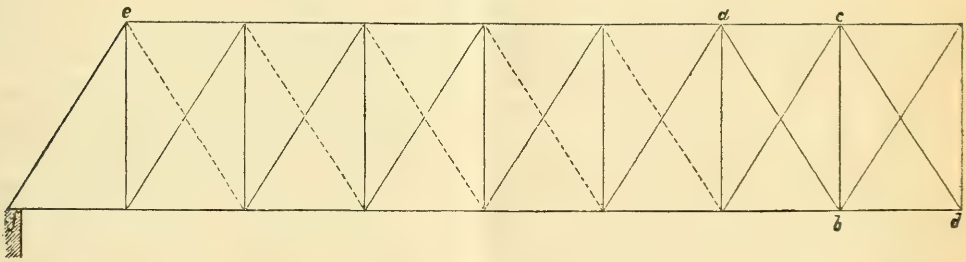
The first effort to most effectively dispose of a given amount of iron in the construction of beams, led, as we have seen to the introduction of the flanged plate girder, of which the tubular system is only a special adaptation. It was soon found, however, that this system, as applied to bridge construction, failed to permit of a proper depth between the flanges, as the thin plates composing the web, yielded by buckling, when their depth was considerable. To obviate this, the lattice girder was introduced, which may be regarded as a plate girder, the web of which has been folded into narrow strips, and these placed diagonally between the flanges. The result of this arrangement is, that while only the same amount of material is used, it is so disposed as to yield less readily to lateral flexure. Still further efforts to increase the concentration of web material, led, with other considerations, to the various kinds of triangular trussing now in use.

The strains on bridges are due to two causes:—the weight of the bridge itself, which acts as a uniformly distributed load, and the weight of the train, which, in its passage over the bridge, develops all the strains we have already investigated.

One of the simplest forms of bridge truss, is that known as the Howe. This truss is composed of top and bottom chords, vertical ties, and inclined braces and counterbraces.

We will suppose a truss constructed on this principle, 200 ft. long, 18.75 ft. effective depth, with the vertical ties 12.50 ft. apart. The truss is thus divided into 16 panels. The roadway rests on the bottom chord. One half of such a truss is shown in the figure.

Fig. 4



We will assume the weight of the bridge itself to be 160 tons of 2,000 lbs., and the weight of a train of locomotives completely covering the bridge to be 320 tons. As we will conduct our reasoning upon a single truss, we must take half of these weights only in our calculations. The length of a panel will be taken as the unit of length. We have therefore the following symbols and values:

L	= length of truss	= 16.
D	= depth of truss	= 1.5.
W	= weight of loaded truss	= 240 tons of 2000 lbs.
w	= panel weight of truss	= 5 tons of 2000 lbs.
w'	= panel weight of load	= 10 tons of 2000 lbs.
w''	= (W + W')	= 15 tons of 2000 lbs.

We will first calculate the horizontal strain in the lower chord, at the end of each panel, beginning at the one nearest the abutment. This strain is maximum when the bridge is covered with its load, and is constant throughout each panel length of the chord. We make use of the formula

$$R = \frac{W}{2\,D\,L}(L\,x - x^2).$$

which we resolve for the successive values of x from 1 to 8. The constant $\frac{W}{2\,D\,L}=5$, and we obtain from the formula the following values for R: 75, 140, 195, 240, 275, 300, 315, 320. We check by applying the formula $R = \frac{L\,W}{8\,D}$ for the central strain, which gives 320 as above. The strain in the top chord is obtained by taking successive values of x from 1 to 7, so that the strain in the first panel of the top chord is the same in that in the first panel of the bottom chord, and so on, the strain in any panel of the top chord being the same as that in the panel of the bottom chord next nearest the abutment.

To determine the shearing strain upon the ties and braces (the counterbraces will be spoken of hereafter), it will be necessary to ascertain in what way the weight is borne by these members. The top chord is kept at the proper distance from the lower one by the braces, and the lower chord with the load is suspended to the upper one by the ties. In this way the whole bridge and load are suspended by the ties to the braces, which may be considered as cranes or derricks.

We have found that the maximum shearing strain at any point occurs when only the longer of the two segments into which it divides the length of the truss is covered with the rolling load, and we have found the amount by which this maximum strain exceeds that produced at the same point when the whole bridge is covered by the load. We will therefore determine the strain on each tie and brace when the bridge is uniformly loaded, and then add this excess.

When the bridge is entirely covered, the whole weight of the 7 loaded panels between the end tie and the centre, is carried by that member, and by it transferred to the end brace. But, besides this, it carries half the loaded panel between this and the abutment, the other half being carried by the abutment. The total weight sustained by the tie, and by it transferred to the brace, is, therefore, that of 7.5 load panels. In like manner, the second tie and brace carry 6.5 panels, the third 5.5, and so on to the centre tie, which carries 1 panel, that is, half a panel from each side of the centre, while the centre braces carry only half a panel each, as they sustain the tie between them. Multiplying these coefficients by W'', we have for the tensile strain on each tie from the first to the centre, produced by a uniformly distributed load, the following values: 112.5, 97.5, 82.5, 67.5, 52.5, 37.5, 22.5, 15.

We obtain the proper augmentations from the formula $\frac{W^1}{2\,L}m^2$, m being the unloaded segment at any point. In using this formula, it is important to ascertain the proper values to ascribe to m. In the present case, to obtain the augmentation for any given tie, we suppose the entire panel between it and the nearest abutment, covered with the rolling load which reaches thence to the furthest abutment. Half of this panel weight is born by the tie in question, and half by the tie next nearest the nearest abutment. The value of m for any tie is, therefore, the distance from the nearest abutment to the centre of the panel which the given tie closes. In this case the successive values of m are, 0.5, 1.5, 2.5, etc., up to 7.5. The value of the constant $\frac{W^1}{2\,L}= 0.3125$, which multiplied by the squares of the above coefficients, gives the proper increment to be added to the values already obtained. We have thus far the maximum strains on the ties, 112.6, 98.2, 84.5, 71.3, 58.8, 47, 35.7, 32.6.

In a beam or girder, when $m = \frac{L}{2}$ the strain produced by the applied load equals $\frac{1}{8}$th of inch. If we applied this rule to the present case, we should get a strain of 20 tons from the applied load, which, added to 4 tons from the permanent load, would give a total of 25 tons for the maximum strain on the centre tie. By the construction of the truss we are now considering, this amount is exceeded by half a loaded panel.

The strain in the braces are deduced from those in the corresponding ties by multiplying the latter by the secant of the angle which the braces make with the ties. That this gives a correct result is easily demonstrated by the resolution of forces. The secant is obtained by dividing the length of the brace by that of the tie. In the present case it equals 1.2; we have then for the maximum strains in the braces the values 135.1, 117.8, 101.4, 85.6, 70.6, 56.4, 42.8, 30. These strains are compressive.

We have now to investigate the subject of counterbraces, which are struts sloping in a direction contrary to that of the braces. In virtue of this definition, the braces of one half of a truss are counterbraces as regards those of the other half, the change of direction taking place at the centre of the truss, at which point the two middle braces abut against each other. If the truss be uniformly loaded, the centre is the point at which the greatest horizontal strain takes takes place. In a truss so loaded no counterbracing is necessary, and this fact points to the rule governing counterbracing in all cases.

Under all circumstances of loading, it is at the point of greatest horizontal strain that abutting braces or counterbraces, throwing the shearing strain right and left towards the two abutments, are needed. It has been already established that this point corresponds to the centre of equal moments of the reactions of the two abutments. When the bridge supports only its own weight, this point is at the centre. But the passage of a train, by unequalizing the reaction of the abutments, causes this centre of equal moments to shift from the centre of the truss. The point is now to ascertain how far it is possible for the weight of the passing train to cause this point to move from the centre of the truss, for beyond this point it will be unnecessary to provide counterbracing to resist the shearing strain. Let us examine the action of a train which advances upon the bridge, covers it throughout and moves off again. As the head of the train gets on the bridge, proportional parts of its weight go to each abutment and are added to the reaction of the permanent load. As these reactions are now unequal, they change the position of the centre of equal moments, which moves from the centre of the truss to a point nearer the advancing train. Counterbracing now becomes necessary as the train advances; the centre of equal moments advances to meet it, carrying the necessity for counterbracing with it. When the head of the train reaches the centre of the bridge, the counterbraces begin to be relieved in an inverse order to that which governed the progress of their compression, the one nearest the centre being the first and last compressed. When the bridge is entirely covered, it relapses into its previous condition of uniform loading, only with a heavier load. As the rear of the train gets on the bridge, the centre of equal moments begins to move forward from the centre of the truss in the same direction as the train, until the rear of the train reaches the centre of the bridge. From this time the centre of equal moments recedes again towards the centre of the truss. On this side also the counterbrace nearest the centre is the first to be compressed and the last to be relieved.

Bearing these considerations in mind, it is very easy to determine the last point at which counterbracing is necessary to resist a shearing strain. We suppose one half of the bridge to be covered with the rolling load, the weight of which is supposed concentrated at the centre of gravity of the half truss. The total reaction of each abutment is then ascertained, and the centre of equal moments calculated. Between this point and the nearest abutment, no counterbracing is required to resist the shearing strain. In our example, the reaction of each abutment from the truss alone is 40 tons. If half the bridge be covered with the rolling load, the abutments will bear an additional weight of 80 tons, of which 20 tons will go to one, and 60 to the other. Adding, we have 60 tons and 100 tons respectively for the reactions of the abutments. The equation for equal moments is therefore $x\ 100 = 60\ (L - x)$, whence $x = 6$. That is, the last counterbraces are required at the distance of 6 panels from each abutment, in our example, which would give two counterbraces on each side of the centre of the truss.

The amount of compressive strain in these two counterbraces, is determined by the following considerations, which, as they involve some of the most important principles of bridge strains, should be closely followed. Under the action of a uniform load, these two members would sustain no compression; on the contrary, if they were so attached to the chords that they could act as tension members, or ties, they would sustain a tensile strain, the one nearest the abutment, *a b*, sustaining one and a half panels, and the other one, *c d*, one half of a panel. If we suppose half the truss to be covered with the rolling load in the manner mentioned, its weight would tend to compress the two counterbraces. But no member of a truss can at the same time sustain or tend to sustain tension and compression, and when both are brought to bear upon it, the actual strain sustained is the difference between the two. Thus, if a certain member was subjected to a strain of 10 tons in tension, and 20 tons in compression, the actual strain sustained would be 10 tons compression. In the present case, the permanent truss weight brings a tensile strain of 1.5 w on the first, and 0.5 w on the second counterbrace, and we must see what compressive strain the weight of the train load brings upon them, and take the difference as the actual strain. To do this, we must take each panel weight of the rolling load separately, and ascertain its effect upon the member in question, the sum of these separate strains being the total compression on the counterbrace.

Each tie sustains one panel weight of the rolling load $= W^1$. The first panel weight (W^1) on the tie nearest the abutment, sends $\frac{1}{16}$th or $\frac{1}{L}$ of its weight through the truss to the other abutment. The second sends $\frac{2}{L}$, the third, $\frac{3}{L}$, the the fourth $\frac{4}{L}$, the fifth, $\frac{5}{L}$, and the sixth $\frac{6}{L}$ of its weight through the truss in the same way, and these all act compressively upon *a b*. The sum of this series is $\frac{21W^1}{L} = 13.12$ tons. Subtracting the tensile strain of 7.50 tons, we have a net compression of 5.62 tons on *a b*. For the strain in *c d*, we must take one more term of the series, and we have $\frac{28\ W'}{L} = 17.50$ tons. Subtracting the tensile strain of 2.5 tons gives a net compression of 15 tons on *c d*. These values must be multiplied by the secant of the brace angle.*

The above investigation shows at what points counterbraces are required to resist the shearing strain of the travelling load. There are other considerations, however, which seem to point to the expediency of counterbracing a truss throughout. There are two qualities requisite in a bridge—strength and rigidity. So far we have considered only the former, though the latter is scarcely less important in structures which, like those in question, are destined to be permanent within the limits of natural decay. All trusses of long span tend more or less to deflect, and if any such structure be designed to sustain a permanent load only, its deflection is generally a matter of but little moment. But when, as in the case of a railroad bridge, it has besides to sustain a travelling load alternately applied and withdrawn, the case is different, for the deflection of the truss under the application of the weight, is followed by an upward spring on its withdrawal. In other words, the tendency of the rolling load is to induce *play*, which in a built structure leads to shocks at the joints, which become eventually loosened and unserviceable. When a truss deflects under weight, the panels are distorted from their original rectangular shape into lozenges, by the sliding of the chords upon the web, like a parallel rule. This distortion cannot occur without the braces yield by crushing or flexure, for the diagonal of the lozenge in the direction of the brace is shorter than that of the rectangle which it originally formed.

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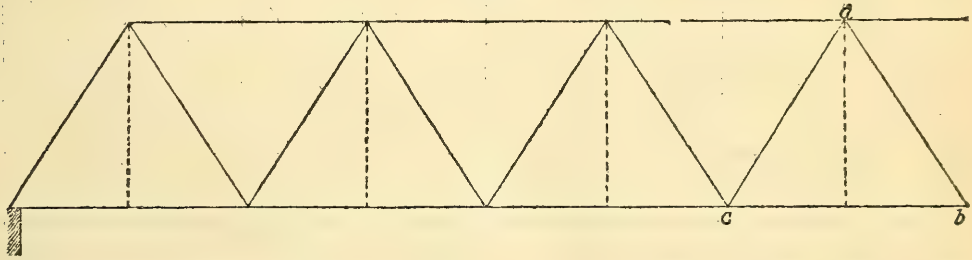
* The strains produced in these members by the rolling load, may also be determined as follows. The weights sustained between *a b* and the end brace *e f* = 6 panels. Of this, $\frac{3.5}{16}$ are sent to the right abutment; therefore the strain on $a\ b = \frac{21W'}{L}$, as before. The weight between *c d* and $e\ f =$ 7 panels, of which $\frac{4}{16}$ go to the right abutment. The strain on *c d* is therefore $\frac{28W'}{L}$ as before.

The braces are therefore the members of the web which oppose deflection. The ties are unaffected by the change of form of the panels while the counterbraces are loosened, as the diagonals in their direction are longer in the lozenge than in the primitive rectangle. When the weight which caused the deflection is removed, the braces are relieved, and the truss springs back against the counters. If, however, while the weight is on the bridge, the play of the counters be taken up, the truss is prevented from recoiling when the weight is removed, and a great degree of rigidity is secured. If the ties of a Howe truss be shortened by screwing up the nuts, the whole truss rises to a camber, and both braces and counterbraces are compressed. If sufficient weight be now brought on the bridge, it will settle to a straight line, compressing the braces still more, and relieving the counterbraces. If when in in this position the counterbraces be tightened up by the introduction of some sort of packing, the truss will be held down to the straight line after the removal of the weight. The strain thus brought on the counterbraces is not cumulative, but is simply that due to one panel weight of the rolling load on each counterbrace throughout the truss.

We will now take up some other forms of straight trusses, and see how their different forms affect the system of calculation adapted for the Howe.

Fig. 5.



The Warren girder, one-half of which is shown above, is trussed with isosceles triangles. Those members, the tops of which incline towards the centre, are braces, and those sloping in the contrary direction are ties. When the panels are very long they are supported by vertical ties, as shown by the dotted lines in the figure. We will first examine the case where these are omitted. In either case the strains in the chords are calculated as in the Howe truss, only for the lower chord, the values of x in the formula

$$\frac{W}{2\,D\,L}(L\,x - x^2)$$

should be from 0.5 to 3.5, and for the upper from 1 to 4. The point at which counterbracing ceases to be necessary to resist the shearing strain of the rolling load is also calculated as before.*

When the bridge is covered throughout by the rolling load, the ties and braces, commencing with those next the abutment, bear respectively the weight of 3.5, 2.5, 1.5 and 0.5 loaded panels. The increments of strain due to the displacements of the rolling load, are obtained from the usual formula, by giving to m successive values of 0.5 to 3.5. These values must be multiplied as before, by the secant of the brace angle. The truss is counterbraced by so arranging the ties and braces that they may sustain both tensile and compressive strains. Assuming the same weights and length of truss as before, we find the point up to which the counterbracing must be carried, at a distance of 3 panels from the abutment. The brace $a\,c$ will therefore be subjected to a certain tensile strain from the action of the rolling load. The amount of this strain is expressed by the equation

$$\text{Sec. }\theta\left(W'\left(\frac{1}{L}+\frac{2}{L}+\frac{3}{L}\right)-0.5\,W\right)=12\text{ tons.}$$

The tie $a\,b$ sustains the same strain in compression.

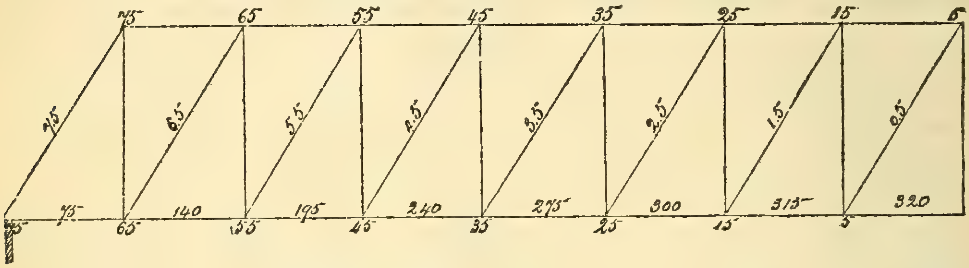
When the vertical ties are added, the braces bear more weight than the ties which slope from their tops. The main ties bear respectively weights in loaded panels, represented by the coefficients

* It may here be stated, that this point is obtained for all descriptions of straight trusses, however the web may be constructed, by the same reasoning as that employed in the investigation of the Howe truss.

3.25, 2.25, 1.25, and 0.25, with values for m in the formula for increments from 0.75 to 3.75. Each vertical tie bears the weight of half a loaded panel, which it transfers to the brace from which it hangs. The braces sustain, therefore, weights of 3.75, 2.75, 1.75, and 0.75 loaded panels, with increments obtained by giving to m successive values of 0.25, 1.25, 2.25, and 3.25. The compression on the tie $a\ b$ from the rolling load is 15 tons as before.

We have now to consider a class of trusses known as compound trusses, in which the web is composed of two or more systems of trussing, crossing each other. In calculating these trusses, the formula employed so far for determining the strain in the chords is inapplicable without a degree of modification which would render its use tedious. The method employed by Mr. Stoney (Stoney on Strains, vol. i., p. 84) is probably the best that can be used in such cases. He deduces the strain in the chords from the vertical strain in the inclined members of the web, and as his system is equally applicable to simple and compound trusses, we will first investigate it in reference to the Howe truss already calculated.

Fig. 6.



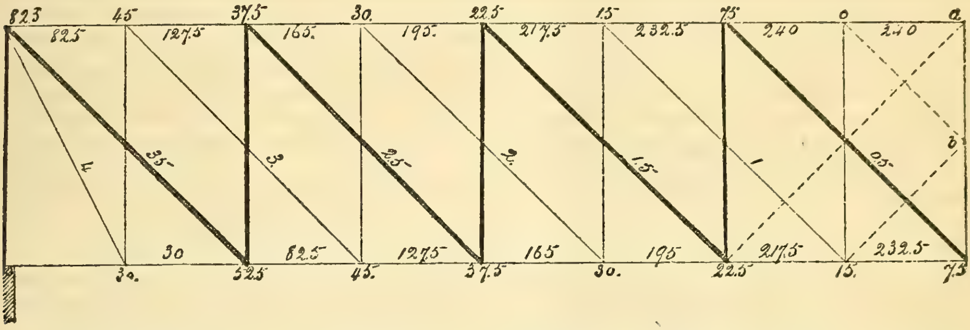
The principle of the calculation is this: the strain in the chords consists of the horizontal components of the vertical strains in the inclined members of the web, and is obtained at any point by the addition of all such horizontal components as occur between the given point and the nearest abutment. These horizontal components are obtained by multiplying the vertical strains by the tangent of the angle θ which the inclined members make with the vertical; as the maximum strain in the chords occurs when the bridge is covered with the rolling load, the first step is to ascertain the amount of vertical strain on the braces when the truss is so loaded, and to write it down upon a sketch of the half truss, as shown in Fig. 6. Keeping the same weight and dimensions as before, we find the value of the constant $w'' \times \text{tang. } \theta = 10$ tons. We write the horizontal component of each brace strain, obtained by multiplying the vertical strain by the constant 10, at its apexes, and by successive additions determine the strain in each panel length of the top and bottom chords, as shown in the figure. The results agree with those obtained by the calculation by moments.

We will now take some of the leading styles of compound trusses, beginning with the Linville.

This truss is composed of two systems of triangles, crossing each other, as in the figure, which shows half the truss. Each system bears half the strain which would come upon it if it alone formed the whole trussing. We will assume a truss bearing the same weight as before, and of the same dimensions, except that the depth shall be 25 ft. In the figure, one system of trussing is drawn with heavy lines merely to distinguish it more plainly from the other. The upright members are posts or braces, the inclined, ties.

The vertical strain on each tie is ascertained by taking each system separately, and supposing it to sustain half weights. It may also be done by a direct estimate, thus: The first tie from the centre, of the heavily marked system, bears obviously the weight of half a panel, that is, half the weight of the segment of the lower chord, comprised between its foot and the centre post. The other half is borne by the neighboring tie of the light lined system. This last bears besides half of the segment between its foot and that of the heavy lined post next behind it. These two halves constitute the one panel allotted to it in the figure. The next heavy lined tie bears the other half of this panel *plus* the half panel next behind it, *plus* the half panel transmitted to it through the heavy lined post which rests on its foot. The next light lined diagonal supports in like manner two half panels, *plus* the panel transmitted to it through the post resting on its foot, the whole making up the two panels allotted to it in the figure. A similar process of reasoning verifies the rest of the weights allotted in the figure.

Fig. 7.

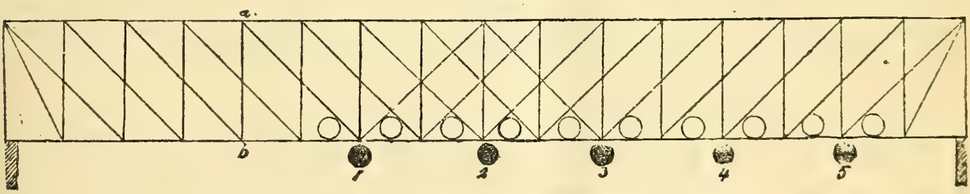


The angle θ being of 45 deg. tang. $\theta = 1$, and the constant tang. $\theta\ w'' = 15$ tons. The end ties of both systems are connected with the end post, as shown in the figure. The tie bearing 3.5 loaded panels transmits a horizontal strain of $3.5 \times 15 = 52.50$ tons to the first panel length of the upper chord, while that bearing 4 panels transmits only $4 \times 7.5 = 30$ tons, to the same member, its tangent being only 0.5. The additions are made as by the figures.

The maximum strains on the ties and posts are found by considering each truss separately. Thus, for the ties in the heavy lined system, we have in the formula for increments $\frac{W' m^2}{2 L}$, $w' = 10$, $L = 8$, and $m =$ successively 0.5, 1.5, 2.5, and 3.5. The increments so obtained are added to the panel weights already determined, and multiplied by sec. θ for the ties.

There is another method of calculating these maximum strains, which may sometimes be useful in checking results obtained by the above process. This consists in ascertaining the strain exercised

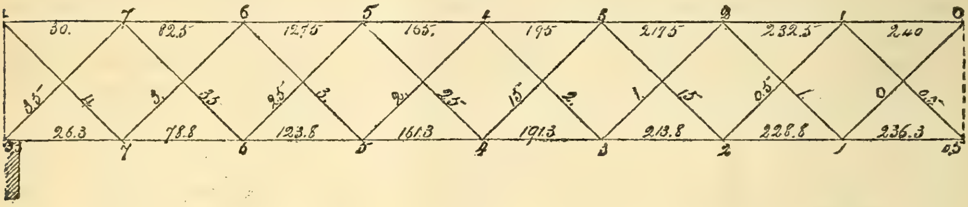
Fig. 8.



upon each tie and post by the rolling load when at its position of maximum effect, and adding this to the strain produced by the bridge weight. For instance, let it be proposed to ascertain the maximum strain on the post *a b* and the tie *a c*. The maximum strain from the rolling load will occur when the truss is loaded from the tie in question to the last tie of the same system, as shown in the figure by the light balls. As each tie of the system to which the members we are considering belong, sustains one half of each of the panel weights adjacent to it, we may suppose the weights resting upon the lower chord to be transformed into those drawn below it in black in the figure. We will now ascertain the amount of shearing strain which each weight sends through the unloaded segment, and their sum will be the maximum strain on *a b* and *a c*, from the action of the rolling load. No. 1 sends $\frac{10}{16} w'$; No. 2, $\frac{8}{16} w'$; No. 3, $\frac{6}{16} w'$; No. 4, $\frac{4}{16} w'$; and No. 5, $\frac{2}{16} w'$; adding we obtain $\frac{30}{16} w' + 1.5\ w$ for the maximum shearing strain in the post. Multiplication by the secant of the tie angle gives that on the tie. An inspection of the above descending progression suggests an easy rule for determining the strains by this method for any tie or post. Take the number of panels in both systems (10 in the present case) in the loaded segment, and make it the first term of a decreasing arithmetical series, of which the ratio is the number of systems in the truss (2 in the present case). The sum of this series multiplied by the rolling panel load and divided by the number of panels in the truss gives the maximum strain in the given members from rolling load.

A counterbrace is needed in the position of the dotted line a, 22.5, capable of resisting a tensile strain equal to

FIG. 9.



sec. θ (w' $\frac{6}{8}$—0.5 w). The heavy lined tie which it crosses is susceptible of receiving a compressive strain of equal amount. The dotted line b, 15, sustains a tension of sec. θ w', and b, o, an equal compression.

Above is shown half of a lattice girder, 80 ft. long, 5 ft. deep, braced with two systems of rectangular trussing; load as in previous examples, traversing the lower chord. We assume the following values:

w = 2.5 tons, panel weight of truss.
w' = 5 tons, panel weight of travelling load.
($w + w'$) tang. θ=7.5 tons.
L=16.

Reasoning as before, we get the strains shown on the above diagram. To obtain the maximum tensile and compressive strains on the ties and braces, we may use either the method by series, or the method by increments, which agree very nearly in their results. In the latter we have L = 8, w' = 5 for both systems, and successive values for m of 0.5, 1.5, 2.5, and 3.5; for the system, 3.5, 7, 6, etc., and of 0.25, 1, 2, and 3 for the other. The summation of series is operated as usual.

Counterbracing is needed from the point 2 to the centre. The brace 1.2 sustains a tensile strain of

$$\text{Sec } \theta \left(\frac{6\,w'}{8} - \frac{w}{2}\right) = 3.5 \text{ tons},$$

and the brace 0.1 one of sec. $\theta\, w'$ = 7 tons.

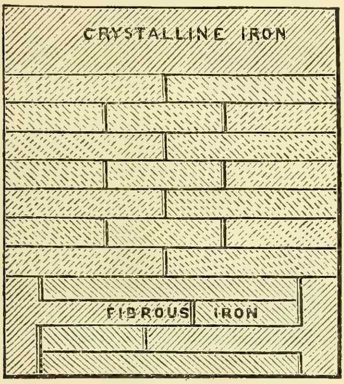
The above example is the same as that given by Mr. Stoney in his treatise on strains, Vol. I., page 111, with the exception that in his example the load traverses the lower chord.

RECENT IMPROVEMENTS IN THE MANUFACTURE OF IRON RAILS.

From "The Engineer."

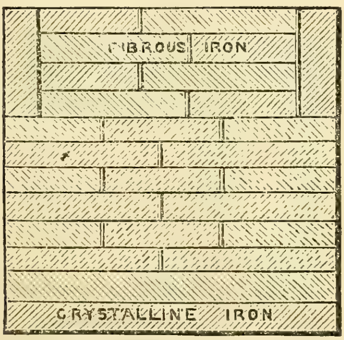
The superiority of steel rails to iron, which is now generally proved to consist chiefly in perfect homogeneity of the wearing surface of the railhead, causes us to regard with much interest every effort to obtain a similar homogeneity in the manufacture of iron rails; for, leaving the required safety in steel and iron out of the question, as a matter of absolute necessity for both, it is from the homogeneity more than from the hardness in the steel that rails of this material derive their excellent results. To prove this in a chemical way, the small amount of carbon, about one-third per cent., compared with the increased stiffness when steel rails are tested under the lever, or ball, of only 25 per cent., as compared with iron rails, leads us to conclude that if ordinary iron rails were made as homogeneous as steel, they would stand very nearly an equal wear and tear. The well-known complaint of lamination and so-called "soft places" in the wear of iron rails proves them an early failure as compared with steel rails, and the increased demand for the latter is, therefore, not to be wondered at. This increased demand seems at present to have exceeded the means of supply, for we are told that the steel rail makers are nearly all full with orders for two years to come; consequently the railway engineer who requires good wearing rails for heavy traffic is placed in the difficult position of not only having to pay an increased price for steel rails, but also having to wait for them, if he can get them at all.

Fig. 1.



Until the supply increases to meet the demand, we must look for a retrogression to superior iron rails from those who can neither afford to pay nor to wait for steel rails. It is these circumstances that bring our attention to a patent rail pile by Messrs. Richardson and Sons, of West Hartlepool, of which we annex a sketch:—

Fig. 2.



The annexed diagrams show two methods of forming the rail pile, No. 2 being that in universal use, No. 1 the patent pile. It will be seen that the old pile (diagram No. 2) is, and must necessarily be built upon the slab of crystalline iron which forms the head of the rail, and must be placed in the heating furnace in the same position, viz., the slab on the bottom, which is the coolest portion of the furnace, the fibrous iron uppermost, exposed to the most intense flame; and in this position it must remain until the several pieces of iron composing the pile are welded together so as to allow the pile to be turned over. The result of this treatment is, that in many cases the fibre of the flange is destroyed, whilst the head is imperfectly welded, and there is produced a brittle rail with a laminated and consequently bad-wearing head. In the patent pile the treatment is entirely reversed, the fibrous iron to form the flange being placed on the bottom of the heating furnace, and thus preserved from the intense heat which is destructive to fibre, whilst the slab which forms the head of the rail, being placed uppermost in the hottest flames, becomes perfectly welded, and the rail produced possesses the maximum of strength combined with perfection of wearing qualities.

The side pieces A, A, are made direct from the crop ends when cut off from the rail, which adds to the cheapness of make. Large quantities have already been made, with the result of better welding in the rail head and more fibrous flanges, which will give a better wearing rail and no breakages. The patent in itself is of little novelty, and we could hardly answer for makers being able to hold it, or at any rate share any royalty from it, for there are other works in the North—such as Darlington and Britannia, and Ebbw Vale, in Wales—which have also constructed a a pile charged in the furnace with the slab up, although in a different way, yet with similarly good results.

We consider this one of those practical improvements which is of the greatest importance for maintaining a good quality, and therefore worthy the notice and material support of railway engineers. We should not undertake to say how much more should be paid for such rails as compared with those made in the ordinary way, and charged with the slab down, because experience will have to prove the degree of their superiority; but for extra rails made to specification we should certainly recommend it, even should the makers ask 10s. more per ton for inserting this improvement alone. The so-called improvements generally tend to deteriorate the quality on an increased make and reduced cost of production; indeed, the history of rail making from the commencement up to the present time shows this, for why do we so often hear the remark that iron rails made nowadays are not half so good as those made a dozen years back, and nobody can contradict it; but the answer is that those rails cost twice as much as these do now, and speaks sufficiently as to the nature of the improvement.

The question of mechanical puddling, by which a bloom could be obtained big enough to form the whole rail—or at least the entire rail-head—without any seams from piling iron together, will be looked upon with the greatest interest, and we hope that the commission from the Iron and Steel Institute now in America investigating the process of Danks' rotary puddling furnace will on their return be able to effect changes which will lessen the labor of puddling and improve the wearing qualities of our rails. Meanwhile we consider the mode of working the rail pile with the slab up to the best next means of obtaining a thoroughly homogeneous rail-head and a tough fibrous flange. We believe the Americans, who now make half the rails they require, have already adopted this mode of working; and indeed, the complaints of English iron rails on some of their roads with heavy traffic are too serious to be overlooked by the rail-making interest in this country.

The Isthmus of Suez.—An important work on the piercing the Isthmus of Suez is being published in Paris; it is a detailed description of the works, and of the machinery and plant employed, and of the processes and materials used in the actual construction of the canal. The programme of this book states that its object is to detail and reproduce by its drawings all the technical elements which were introduced in the progress of the work. This is the first time that these elements have been thus grouped, the numerous volumes which have already been published bearing on the political, picturesque, or commercial aspects of the work of M. Ferdinand de Lesseps.

It is M. L. Monteil, engineer of the Suez Canal Company, who has been attached to the gigantic undertaking since 11 years, who has undertaken this publication. The text will be as concise as possible; with the history of the work and the description of the drawings it will give in detail all prices, and the performance of each item of the plant. There will be 300 plates engraved on copper, giving drawings in detail of the works and the machinery. The work will be divided into ten series.

1. Towns and encampments. Plans of the maritime and fresh-water canals. Geological sections of the Isthmus, and profiles of the ship canal.
2. Distribution of fresh water.
3. Jetties, lighthouse, and works of construction.
4. Services of transport.
5. The small dredging machines; the application of the endless bands and spoil distributors.
6. Dredging machines employed in the canal; spoil boats and lighters.
7. Dredging machines, elevators, etc.
8. Dry cuttings. Wagon and engine shops.
9. Repair shops.
10. Materials for maintenance and lighting.

It will be seen that it promises to be a considerable work. All the materials for the text and the plates are ready, and at present they are being prepared for publication. This work, which will confer lasting honor on its author, is intended to render special service to those engineers who may be called upon to study or carry out great undertakings of public interest analogous to the Suez Canal. But it will interest all those who wish to appreciate the efforts made unceasingly during 15 years to open a new route to the commerce of the world.—*Engineering.*

European Products in Japan—The "Japan Times" says, that in the interior of Japan there are to be found shops exclusively for the sale of European goods, and that where few, if any, Europeans have visited or passed through. Soaps, perfumes, clocks, colored engravings, and beer seem to be in general demand, while some shops deal exclusively in tables and chairs after the European fashion.

SEWAGE IRRIGATION.

From "The Engineer."

The chief points to be attended to by agriculturists in a practical sense, if they desire to reap that which they sow, are undoubtedly the manuring of the land, the draining of it, and a skilful and judicious rotation of crops. Most farmers understand the first, so long as it does not deviate from the stereotyped methods practised from time immemorial, but, comparatively speaking, few the second and third. Yet, upon an accurate comprehension of these essential branches of the subject, a due appreciation of their paramount importance, and a regular and systematic adoption of them in practice, depends unquestionably the permanent fertility of the soil. It is true that land is occasionally met with, which, from a peculiar geological formation and other favorable influences of situation, is so exceptionally fertile as to require but little manure. It is not, however, the lot of one farmer in a thousand to have his tent pitched among these prolific oases. In many instances, if the land does not produce the results which may be fairly expected of it, the usual cry is that it wants more manure, when, in fact, it may be already choked with it. Nevertheless more manure is applied, while the other two points to which we have drawn attention are scarcely thought worthy of notice, and thus the attempt is made to compensate by the wholesale unscientific application of the one for the total neglect of the others. The soil is stimulated or forced to do that which it would accomplish spontaneously with a trifling assistance, were it treated in a proper and scientific manner. The mania which some farmers have for curing all the evils or shortcomings of land by an unlimited use of manure, was well demonstrated when the utilization of sewage by irrigation was first introduced. Many owners and proprietors of land tried the system on a small scale, and, as might be expected, the result was a complete failure. They imagined that nothing more was required than to deluge the land with the new fertilizer; and that magnificent crops would follow as a matter of course. But with one exception, namely, that of grass, magnificent crops did not follow, even when the method was tried on a large scale, and by those who understood as much of the principle as was understood at that time. It is very unfortunate that grass should evince such an avidity for sewage, for it has led to a very reckless mode of distribution, which has been adhered to in the case of other crops with the most unsatisfactory results. Had grass crops demanded the same care and discrimination in the application of sewage as the cereals and roots, the system of sewage irrigation would be in a far more advanced stage, both theoretically and practically, than it is at present.

Hitherto the principle of sewage irrigation has been regarded as a superficial irrigation only, the fertilizing fluid not being supposed to penetrate into the ground much deeper than the roots of the plants and crops growing upon it. Hence arises the great, and it must be acknowledged in some instances, the insuperable difficulty of carrying out the irrigation principle. Obviously a very large area of land is required upon which to utilize the sewage. Without going into the merits or demerits of the various proportions, which different authorities have laid down ought to obtain between the numerical strength of the inhabitants of any given town and the number of acres necessary to utilize the sewage of that town, it may be assumed that the average which places the ratio at 100 people to the acre is a fair one. If a farm were entirely laid down in grass this average would be less than that required; but as experience has shown that the sewage of a town cannot be remuneratively utilized by its application to a single crop, it is a correct one under general conditions. Supposing, however, that it could be put at 150 persons to the acre, then, taking the population of a city at 500,000, over 3,000 acres would have to be devoted to the purposes of sewage utilization. This quantity of land is not acquired without some difficulty, more especially when it is borne in mind that there are several conditions to be fulfilled with respect to situation, levels, and physical contours, upon which altogether depends the financial success of the undertaking. As a rule, a certain quantity of land can generally be obtained for irrigation purposes, but this amount is very limited ; and moreover, for many reasons, may not be well adapted to the end in view. Take the case, for example, of a town lying in a hollow, as a vast proportion of towns do. If there are no fields contiguous thereto at about the same level, it becomes necessary to pump the sewage up to a certain height before it can flow over the land situa ed at a higher elevation. It must be borne in mind that while we acknowledge these difficulties attendant upon sewage irrigation, which have retarded the development of the principle in its integrity ever since it was practically applied, they constitute no argument against its value, which has been demonstrated too convincingly to admit of any doubt in the mind of any disinterested and impartial judge.

From what has already been stated, it will be manifest that if the irrigation principle could be applied to a much smaller area of land than is more generally considered requisite, a considerable gain in every respect would be obtained. It would be not only possible, but easy, to procure a minimum quantity of land in many instances where the maximum, or what is now considered the necessary, quantity is unattainable. The problem connected with the utilization of sewage by irrigation is to utilize the maximum quantity upon the minimum area of land. It may be urged that this has been virtually accomplished at Craigintenny for many years past ; but the soil there is of a peculiar nature, and not often met with. Besides, the correct definition of the term "utilization" does not signify a mere deluging of fields of grass with sewage, but the application of it in such a manner as will yield the most remunerative return under the circumstances. It must not be forgotten that the purification of the effluent water is a point to be attended to, as equally essential with the utilization of the sewage. It is, in fact, more so; for, as the effluent water must sooner or later find its way into some stream or watercourse, care must be taken that the contents are not polluted thereby. It has been before remarked that under the present system the sewage penetrates but an inconsiderable depth into the soil; but were it caused to penetrate much deeper, as it would always be in contact with it, the process of purification would still go on, and the same results obtained, with a considerably less superficial area of soil. In a word, the purification of the sewage would not depend upon the superficial but the cubical contents of the land. This is the plan proposed by Mr. Denton, and it deserves serious consideration at the hands of all those interested in this great question. It will at once be seen that it signifies deep drainage of the land, as it is proposed to allow the sewage to penetrate to a depth of from 4 to 6 ft. before passing off through the drains. This plan possesses several features to recommend it. The first is that a much smaller number of acres will suffice for the purification of the sewage of a town or district ; the second, that deep draining of the soil, so much neglected by farmers, will be imperative, and the third that the land will be more thoroughly manured than by the present process of superficial irrigation.

The expense of carrying out this method will undoubtedly be greater than the cost of that now in use ; but, provided the undertaking pays, that is not an insuperable obstacle. Neither would the cutting of the trenches and the laying of the necessary pipes be so difficult or so expensive a matter as might at first appear. Messrs. Fowler have machines expressly designed for these purposes. Their patent "knifer" will open ground at almost any depth ; and in heavy clay soils, where it is not advisable to bring the subsoil to the top, the machine can be driven through the ground without materially disturbing the surface. The next operation, that of laying the pipes, could be accomplished with equal facility by means of their patent draining plough, which is adapted to be worked by the ordinary plough engine. It can be used as a mole plough, and will lay pipes in stiff clay soils at a depth of 4 ft. with perfect ease and safety.

If we examine into this proposed mode of purifying sewage, in order to produce a pure, clear, effluent water, the nature of the soil must be taken into account. Sewage must be purified in a double sense, mechanically and chemically. By the present irrigation system the former is effected partly by filters, extractors, and some other mechanical agency, and partly by filtration to a small depth through the soil, and the latter by the assimilating powers of the plants, with the roots of which the liquid is brought into contact.

If, however, we irrigate the land cubically instead of superficially, a large portion of the sewage must be purified both mechanically and chemically by the soil alone. The question, then, is : are all soils capable of acting in this double capacity? Certainly not. A peaty soil is well calculated to act both as a filter and a chemical purifier, but many others will not effect the double object. It cannot be too carefully kept in view that although water may be completely deprived of all its mechanically suspended impurities, and to all appearance be perfectly pure and clear, it may, nevertheless, be chemically exceedingly impure, and totally unfit to drink. It is notorious that water slightly contaminated with sewage has not only a clear, sparkling appearance, but, owing to its saline ingredients, is rather agreeable than otherwise to the taste. It is alike deceptive to both the eye and the palate. Accurate chemical analysis is the only test to be depended upon in determining the purity of water. Another point to be kept in mind with reference to the proposed mode of irrigating the land to the depth of several feet, is whether it would not after a certain time, become so completely saturated with sewage as to be incapable of any longer fulfilling the duty required of it. Although experience has hitherto furnished us with no information on this head, yet there is no question that such would be the case. Manifestly the land would be literally a filter for the sewage. All filters, from the domestic specimens to the beds necessary for water-works, become clogged after a certain time, and must be cleaned out. The time they will last without cleansing depends altogether upon the character of the liquid they have to filter, and the case is the same with the land. Accordingly, as the sewage is more or less charged with solid ingredients, so will the land become foul and clogged in a short or a long period. But the land, when in this condition, would have to be cleansed, which could only be accomplished by abstaining from any further irrigation. In the interval which the soil would require to return to its normal condition—which would certainly be two or three years at least—the sewage, which is continuous in its discharge, would have to be turned on to some other land. It, therefore, is by no means certain that the total quantity of land required in 10 or 20 years would be so very much less than that which would be necessary under the present system of superficial irrigation. One thing is certain, that if this method was once adopted, and more land was required, it would have to be obtained at all hazards, even if houses had to be pulled down to clear the ground.

THE EUPHRATES VALLEY RAILWAY.

From "Journal of The Society of Arts."

The report from the Select Committee on the Euphrates Valley Railway has been published, with the evidence of several distinguished Oriental travellers and eminent engineers, upon the route best fitted to secure a direct communication between this country and our Indian Empire. The Committee have, for the present, agreed to report to the House of Commons the evidence they have gathered, leaving the many important questions raised until the sittings can be resumed at the commencement of next session. Apart from certain minor questions of more or less relative consequence in regard to the direction which the line of railway should follow, we learn there is a divergence of opinion upon the desirability of using the Black Sea or the Mediterranean as the basis of operations. These points were clearly explained at the outset by Sir Henry Rawlinson, the first witness called, who speaks with the authority of personal knowledge, gained by 12 years of residence and travel in Turkish Arabia. We learn from his description that several routes have been recommended which possess certain advantages, and are therefore deserving of the consideration of the Committee. The first is a route which has been proposed by the Turkish Government, and for which the Porte gave, or offered, a concession as long ago as 1866 or 1867. This was intended to connect Constantinople with the Persian Gulf. It was to start from Scutari, opposite Constantinople ; then it passed along to Izmid, Kutayich, Kara-Hissar, Kumèh, and Kaisarich to Aleppo, and then down the Valley of Euphrates to Bagdad and Bassorah, and from Bassorah to the head of the Persian Gulf. The distance was estimated at 1,700 miles, including a branch from Aleppo to Scanderoon. It was 800 from Constantinople to Aleppo, including the Scanderoon branch of about 120 miles; and it was 900 miles from Aleppo to the Gulf. The second is what is generally called the "Andrews" line, or the well-known Euphrates Valley route, which is the same as the lower portion of the route described, but the essential difference being that the terminus is at Scanderoon instead of Constantinople. The distance is estimated at 850 miles, whereas it should be in reality 1,000 miles. The third route, which has been strongly recommended to the Government by Col. Herbert, the present political agent in Arabia, would also leave the Mediterranean at Scanderoon, but it would subsequently pass by Aleppo across the Euphrates at Bir or Orfah, which is the ancient Edessa, and so on to Diarbekr, Nisibin, Moosul, and then along the Tigris to Bagdad and B ssorah. This route would be 100, or perhaps 150 miles longer than the Euphrates Valley line, as it makes a considerable detour to the north-east, but it has the advantage of passing through a number of large cities and centres of trade, and lying generally among settled and populous districts. These are the three routes which exist between the Mediterranean and the Persian Gulf.

There are, besides, two or three routes from the Black Sea which ought to be considered. There is, in the first place, a route which has recently been advocated. It leaves the Black Sea at Jereboli, near Trebizond; it crosses the mountains to the Valley of the Euphrates, at Erzingam; it then takes a steamer and passes down the Euphrates to the point nearest to Diarbekr; it then crosses to Diarbekr and follows the Tigris down to the sea by steamer. This would be about 950 or 1,000 miles, partly water and partly railway, but the water communication would be only practicable for a few months in the year, and then only downwards. There is another route which leaves the Black Sea at or near Samsun, and follows the high road to Sivas; from Sivas it would follow a line by Malatieh and Diarbekr, and from Diarbekr it would follow Colonel Herbert's route to Bagdad and Bassorah. This would be about 1,000 miles in length. There is another route also from the Black Sea, although the project has not attained any substantive form, and that is a line from Trebizond to Erzeroom, across the mountains, and from Erzeroom to Van, and then down the Betissú to the Tigris, above Moosul, and from that point along the same line as the last route. This line would cross the range of the Taurus in about its most difficult and impracticable position, and would be impossible to effect, the country being cut up by a succession of precipitous ravines, mountain torrents, and impracticable defiles. Other lines have been projected connecting Europe with India, but this question involves much larger considerations than those affecting the mere limited question of connection between the Mediterranean and the Persian Gulf. There are, according to Sir Henry Rawlinson, three great lines which have been projected to connect Constantinople with India. The first would pass Constantinople along the northern or high road to Erzeroom; from Erzeroom, it would cross the Persian frontier to Khoi and Tabreez, and so on to Teheran, the capital of Persia; from Teheran it would pass to Shahrood and Mushed; at Mushed it would run south-east to Herat, and so on to Kandahar, and through the Bolan pass to Shikapoor and Sukkur, where it would join the Indus Valley base. The length of this line would be nearly 3,000 miles, which is not quite so much as the line which connects Sacramento with New York, and which distance is traversed in a week. The second line also leaves Constantinople, and follows the central route through Asia Minor, or, as it is now generally called, "the telegraph route," being the line along which the Turkish wires which carry our messages to India are placed; it passes by Angora, Yusgat, Sivas, Diarbekr, and Moosul to Kifri, which is the nearest point to the Persian frontier on that line, and where our telegraph turns off to Persia. From Kifri it would cross the Persian frontier, and ascend through the "gates of Zagros" to Kermanshah, and so on by Humadan to Teheran, where it would join the route contemplated to the Indus Valley. The length of this line would be about 3,200 miles; it presents engineering difficulties at two points, namely, the descent of Taurus and the ascent of Zagros, but it has many compensating advantages. There is another, or third route. From Constantinople, it would follow the same line, as far as Bassorah, as No. 1 of the limited routes; that is to say, it would pass by Kutayïeh and Kumèh to Aleppo, and along the Euphrates Valley to Bagdad and Bassorah, being absolutely the same as the line proposed by the Porte. From Bassorah it would circle round the northern and eastern shores of the Persian Gulf, passing by Bushire and Bunder Abbas, and would then follow the coast of Mekran to Kurrachee. This would be somewhat shorter than the upper line, about 2,900 miles, and from Bassorah, along the shores of the Persian Gulf, with the exception of Bushire, there is not a town worth speaking of, and a very scanty population—that is to say, throughout the whole distance from Bassorah to Kurrachee.

The evidence given by Colonel Chesney bears more especially upon the advantages of the Euphrates Valley line in particular, and the nature of the country through which it passes. He observes that the route from Trebizond by the Tigris would be highly advantageous to Russia, but of little or no service to this country. The port is an open one, and therefore highly objectionable, with steep mountains behind it, and the Taurus beyond them. In the event of a war with Russia, and Russia having the command of the Black Sea, she would be able to shut up the terminus of the railway upon the Black Sea; whereas, if the terminus were on the Mediterranean, England would have the command of it, as being easily defensible, and there would be an excellent port at which to land an army. In his opinion, therefore, the line by the Euphrates from the Mediterranean is the only one desirable for the English nation to construct. The chief engineering difficulties occur at the first stage from the sea, in the 15 miles traversed from Swedia, or Scanderoom, to Antioch; all the rest is easy. There would not be a single tunnel or cut to make. The population along the proposed line is very considerable. The Arabs would number between 2,300,000 or 2,400,000 ; they come in the summer, and go away again; therefore, there is a large population—several towns with considerable commerce. A great traffic might be established with this country from points where there is already a large trade. The imports through Aleppo are upwards of two millions, coming from the line of Arabia, and the exports are not far short of the same amount. The Tigris has its commerce also, but the commerce of the Tigris is not so great as that of the Euphrates. The land is favorable to the growth of cotton, linseed, corn, and everything which is produced in India. In the early spring, clover and grass may be seen growing 9 ft. in height. It is the finest alluvial soil in the world, and is much more fertile than the land in the valley of the Tigris. There is an existing traffic passing by means of the caravans, and there has been a communication through Arabia since the time of Abraham; it has never ceased. The caravans go through, and hardly ever meet with any difficulty from the Arabs, except a slight payment, which the sheik expects. There would be no obstruction, and labor would be readily obtainable for the construction of the works along the line. With regard to climate, the deaths from fever and ague are not numerous, and exposure would be better to bear than if exposed on the Red Sea. In comparison with the journey by the steamer on the Red Sea, the railway would be easier, the current of air would be more refreshing ; in the case of the former, the steamers are often forced to turn round so as to get air into the ship, to save the passengers from the intense heat. For the conveyance of the light, valuable goods, mails, passengers, troops, and treasure, the Euphrates route would be the best, and both lines would assist each other ; there are people and commerce enough to occupy both. The distance would be, from London to Brindisi, 1,504 miles; from Brindisi to Selucia, or Scanderoon, 900 miles. The line of the Euphrates, along the river, as proposed for the railway, is 850 miles, that is from the sea to Bassorah; then, from Bassorah to Bombay, the distance is 1,690 miles. The total distance from London to Bombay is 4,944 miles. The route, *via* Brindisi, Suez, and Aden, the distance is 5,472 miles, from London to Bombay, and from London to Kurrachee it is 5,247 miles. The difference in favor of the Euphrates line is, from London to Bombay, 528 miles, and from London to Kurrachee, 803.

With respect to the arrangements that it would be necessary to enter into with the Turkish Government, and the means by which the capital to complete the undertaking could be raised, we learn the full particulars in the evidence given by Sir George S. Jenkinson, Bart., a member of the Committee. From conversations and written communications with the Turkish Minister, his Excellency, it appears, on every occasion expressed himself personally most anxious on the subject, and that the completion of the project would be especially favored by the Sultan. The result of these interchanges of opinion was reduced to a written document.

The Turkish Government consents to the construction of the railway on its own account, from Alexandretta to Aleppo, and from Aleppo to Bagdad and Bassora, at the head of the Persian Gulf, under the direction and working control of a mixed committee, to be jointly appointed by the the English and Turkish Governments, and upon the following conditions :—1. The funds to be raised by means of an Ottoman loan, the interest of which to be counter-guaranteed by England, at the rate of 4 per cent. per annum, and one per cent. for sinking fund. 2. The proceeds of such loan, when raised, to be deposited in the Bank of England, in the names of the mixed committee, and to be applied by them exclusively for the construction of the railway, and the provision of the necessary rolling-stock, and for no other purpose. 3. All the land necessary for the railway, and for all the works in connection therewith, to be provided for by the Turkish Government. 4. In order to secure, with regularity and certainty, the payment of the interest upon the loan, the following stipulations to be agreed upon and enforced :—1st. The net income proceeds of the working of the railway when made, wholly or any part of it, to be paid into the Bank of England, and applied exclusively to the payment of the interest of the sinking fund. 2d. The customs duties and port charges of the ports of Alexandretta and Bassorah, as well as certain revenues and other resources of the province through which the railway may pass, to be assigned by the Turkish Government to the mixed committee, as a security for the payment of the interest of the loan and of the sinking fund. 5. The Turkish Government to guarantee to England the privilege of the conveyance of troops at all times by the railway to and from this country and any of Her Majesty's Eastern possessions, and at a rate not exceeding that which will be paid for a conveyance of troops belonging to the Ottoman Empire, and upon such other conditions and regulations as shall be settled and agreed upon by a convention between the English Government and the Sublime Porte. 6. The transport, free of any charge, at all times, by the railway, of all English mails to and from this country, and any of Her Majesty's Eastern provinces. 7. Until the extinction of the loan, by the repayment of the principal and interest, the English Government and the bond-holders, as represented by the committee, to have an absolute mortgage upon the railway, and land, and works.

GASES FROM THE BESSEMER CONVERTER.*

By Mr. G. J. Snelus, A. R. S. M.

This investigation was undertaken in the hope of solving some of the difficulties connected with the spectroscopic observation of the Bessemer flame, and also as likely to afford a further insight into the nature of the process going on in the converter.

The gas was collected for analysis by means of an iron gas pipe, having a swan-necked trumpet mouthpiece of fire-clay, which was dipped into the mouth of the vessel after it had been turned up. The gas from its pressure in the converter, rushed through the pipe with some velocity, and after the whole of the air had been swept out, glass tubes were attached, and when filled with gas, at particular periods of the blow, were hermetically sealed up with the blow-pipe before removal.

The gas was analyzed in some cases by two different methods, and the duplicate results were found to agree.

The following tabular statement shows the composition of the gas at different periods of a blow lasting 18 minutes:

* Abstract of a paper read before the Iron and Steel Institute, on the Composition of the Gases evolved from the Bessemer Converter during the Blow.

	No. 1 Taken 2. from start.	No. 2 4.	No. 3 6.	No. 4 10.	No. 5 12.	No. 6 14.
Carbonic acid	10.71	8.57	8.2	3.58	2.3	1.34
Carbonic oxide	None.	3.95	4 52	19.59	29.3	31.11
Oxygen	.92	....	Absent.	Absent.	None.	None.
Hydrogen }	....	88	2 00	2.00	2.16	2.00
Nitrogen }	88.37	86.58	85.28	74.83	66 24	65.55
Hydrocarbons	....	....	....	....	None.	....
	100.00	100.00	100.00	100.00	100.00	100.00

On dissecting these results we find that the oxygen corresponding to the nitrogen in No. 1 is sufficient to oxidize not only the 4.43 parts by weight of carbon that are contained in the gas, but also 11.91 parts of silicon, and as these two bodies are practically the only ones being burnt from English Bessemer iron at this period of the blow, we may take it that these are actually the proportions in which carbon and silicon are now being got rid of from the metal. And this is exactly what analyses of the metal at this stage show, for it was found in one instance that metal containing 3.57 parts carbon and 2.26 silicon at the commencement, lost .53 parts of carbon against 1.305 parts of silicon in the first few minutes. Analyses of the gas from another blow about the same time, made by W. Thorp, F. C. S., of the Rivers' Commission Laboratory, show practically the same results. Sample 3 shows that 5.27 parts of carbon are being burnt along with 11.74 parts silicon. Sample 4 was taken after the commencement of the "boil" when the complete carbon specimen had become permanent. It shows quite a different result from the previous analysis, the large percentage of carbonic oxide now present explaining why the flame has become so much more luminous. We now find that 9.6 parts of carbon are being oxidized along with 6.25 parts of silicon. Sample 5 was tested specially for hydro-carbons; but none were found. Sample 6 shows that 13.45 parts of carbon are being burnt at this period and only .46 parts of silicon, which corresponds with analysis of the metal, these proving that the last traces of silicon go off very slowly.

The author considers that the reason why carbonic acid is formed during the first part of the blow, and carbonic oxide at a later stage is to be found in the increase of temperature during the blow. This agrees with experiments of Mr. Bell, who proved that at a low temperature carbonic acid was more stable than carbonic oxide in contact with iron, but that at a high temperature the reverse was the case. It also agrees with general observations. As a general result the comparison of the gas analyses with spectroscopic observations, shows that the reason why we get a continuous spectrum at the commencement of the blow is that we have then only white hot solid matter to look at, there being no actual flame, and the temperature being too low to give the specimen of carbonic acid, while later in the blow we have an abundance of carbonic oxide burning at the mouth of the vessel, which is also at a very high temperature, and, therefore, we get a carbon spectrum which is distinct from other carbon spectra yet seen, because we have not yet been able to examine the spectrum of carbonic oxide at the particular temperature of the Bessemer flame. Mr. Snelus believes that Deville's theory of the increased luminosity of flames under great pressure being due solely to the increase of temperature, is applicable to the great luminosity of the Bessemer flame compared with that of carbonic oxide burning at a low temperature. On comparing the gas from the Bessemer converter during the latter part of the blow with blast furnace gas, and with analyses of gas from Siemens' producers, given by the writer, it is seen that the former is as valuable a fuel as any of them, and as works using 1,000 tons of pig per week is sending this gas to waste at the rate of an equivalent of 25 tons of coke per week, its economical application becomes a point of great importance.

The writer believes this could be accomplished in a simple manner.

THE NORTH SEA CANAL.*

"A visit to the Suez Canal in my canoe (which was related in the "Times" a few years ago) enabled me to compare the North Sea Canal with that larger, more mundane, but not more remarkable example of human industry and patience, cutting the land in two to abridge the seas, levelling whole mountains of sand, battling with deep tides and hidden springs, stormy waves, and thousands of dubious or impatient shareholders--by far the most difficult obstacles for the venturous capitalist and the clever engineer.

"I have already explained that the North Holland Canal, which was cut to save a roundabout from Amsterdam by the Zuyder Zee, is more than 50 miles long, and enables large ships to enter Holland at its extreme northern end. But this canal is too long, too narrow, too tortuous, and too shallow for the increasing length and depth of our largest merchant vessels. To save time, then, and much trouble and transhipment, the new canal opens to the west instead of to the north. It is 15 miles in length instead of 52. Its depth is 26 ft. available instead of 16 ft., and no bends or sudden turns obstruct the passage anywhere. Six years ago this work was begun by the well-known English contractor, Mr. Lee. With Mr. Hawkshaw and Mr. Dircks to plan, and Mr. Freeman to execute, and a wealthy company to pay for it, all good folks ought to expect success.

"At present the work is precisely in that condition most interesting to inspect, being just beyond the state in which any doubt can remain as to ultimate success. Very likely this success will sap the other canal, and reduce Nieuwe Diep to a marine depot; perhaps it will also draw the golden tide from Rotterdam, but perhaps, too, the merchants there will shift their quarters to the better entrepot of Amsterdam, and yet perhaps, indeed, when all is done a certain German Prince will stretch out his iron hand and ask for the new road, and very graciously thank those who made it for him.

"First of all, locks are being placed on the east, to enclose an artificial lake about 12 miles long, at one end of which rests Amsterdam, and a deep channel is dredged along this lake, with two banks gradually rising into solid tow-paths. Minor canals, in all about 12 miles long, are left on either side to communicate with the little towns now on the shares of the Y, but all this intermediate area of water will be pumped out, and so nearly 12,000 acres will thus be reclaimed. No one can say how much this new territory will sell for, but an acre I asked about at random was valued at £100. The average may be ½ of this sum.

"The dredging is far better done than it was on the Suez Canal. The machinery has been steadily improved and simplified, and the latest and best appliance was only completed a few days ago. This consists of a tube resting near the ooze at the bottom, and containing a shaft with a centrifugal pump, which draws up the sand and water bodily—about half of each in the mixture—and forces it along wooden pipes floated on the surface of the water, and flexibly jointed by leather hides. The slush is thus poured through a conduit about 300 ft. long and 1 ft. broad, which resembles a huge black snake coiled and asleep on the water, and with its tail turned over the bank at the side. Through this tail, even when it is raised 8 ft. above the level, a copious fluid rushes, black as ink, but fertile for the next 100 generations of cheese-making Hollanders. So simple is this plan that already it is being applied to the great banks of the Danube, and I saw boxes full of the hide joints being sent to the Sulina mouth. Not many, but still some, curiosities have been found in the ground dug up or dredged for the canal. An enormous mammoth's skull and huge bones of the same fill one end of Mr. Freeman's office, and these ought to be in the British Museum, and could, I believe, be readily forwarded if properly applied for. One human skull has been dredged out 9 ft. below low-water mark, and I am enabled to bring it home. The size is large, the frontal part very small, the forehead being scarcely more than an inch in height. One or two pottery pieces have also been found, and, of course, plenty of shells. As no gravel has appeared in the matter dredged from below, it seems plain that the idea is erroneous which has long suggested that an ancient mouth of

* From Mr. Mc Gregor's letter, "London Times," through "Engineering."

the Rhine once led through Holland at this spot.

"The banks thus formed are gradually raised above the surface to the average of 3 ft., and then a layer of stiff clay is placed over the sand. On this is spread a sort of matting of loose reeds, which grow profusely in every lagoon. Long twigs of the willow-like tree, named 'rys,' are then laid down, and stakes about 4 ft. long are driven through them in rows, while a regular-twisted wattling of 'rys,' is securely worked into these, and the whole assumes a most business-like aspect, utterly different from the loose, unprotected sandbanks of the Suez Canal, which latter the water, the wind, and their own weight all conspire to ruin. Better than all the rest, a plant called 'helm,' which grows naturally on the sand-hills, is being planted like cabbage rows upon the new-formed banks, and this rapidly takes root, and binds all together.

"This plan is to be tried on the Suez Canal, but probably the climate and the larger proportion of salt water in the Egyptian sand may prevent the 'helm' from growing there. At the end of the lake we reach the 4 miles of solid sand and elevated ground which had to be cut through before the western shore of Holland is attained. The deepest cutting is not more than 100 ft., and is a mere matter of digging and carrying away. At length we come to the locks close to the sea. These are of enormous size, 500 ft. long and 60 ft. broad, with a depth over the sill of 30 ft. The stone-work facing of these is beautifully fitted, and the 25,000,000 of Dutch bricks here laid are a model of bricklaying. The width of the canal from centre to centre of the towing-path is about 500 ft., but at the edge of the main channel only 200 ft., and 80 ft. at the bottom; but this gives ample room for the largest vessels to pass each other. Now we are in the thick of the 'dunes' or sand-hills, Holland's western wall. They are not bare, but rather jungly in their look, and hares and rabbits, and curlew and spoonbills are plentifully found by the sportsmen on these wilds. Climbing this barrier we can look down on the two gigantic pier arms that stretch forth boldly into the stormy sea, and which keep steadily lengthening every week, and gradually bending in their ends to form the grand entrance to the new-born port. Nearly one-half of these piers is already finished, and this not by casting in the huge blocks promiscuously, as at Port Said, but by placing every one on its proper bed, well-fitted to its neighbors, and bound by iron-ties, so as to form a smooth-faced, upright sea-wall. The blocks thus placed are made of concrete and Portland cement, in weight about 10 tons each, just as at Port Said, and thousands of them are still on the shore waiting to be run along the pier, and then to be hoisted up by the iron neck of the great steam 'Titan' which will swing them into their final beds."

SOFT IRON AND STEEL CASTINGS.

From "The Iron Age."

The demand for some practical process which will furnish a reliable and inexpensive method of making malleable iron and steel castings, has attracted the attention of inventors to this line of production without, however, any great success hitherto. The latest process yet published is announced by the "Scientific American," and is the invention of Mr. Richard Yielding, of New York. The invention consists first, in making malleable iron or steel castings by casting the metal into hot moulds capable of inclosing it and protecting it from the atmosphere, and then allowing the moulds to cool gradually in a oven with a decreasing temperature. By this method the castings, it is claimed, will be annealed when cool, and the tedium and expense of making castings malleable is avoided, besides producing a softer and more homogeneous metal. A second process consists in lining the moulds with a decarbonizing substance, in order to more completely decarbonize the metal after being poured into the mould, and to enable it to remain sufficiently fluid to pour, thus making either soft castings of the nature of wrought iron, or steel castings, with less carbon than can be cast in the ordinary way.

The moulds used are made of plumbago

and fire-clay, ground carbon and like substances, capable of resisting great heat, and are raised to a white heat before being used, either in an oven or by other suitable means. The castings may be made directly in an oven, or the moulds placed in the oven after filling in such a manner as to protect the metal from the atmosphere and prevent possibility of chilling. The advantages claimed are the production of softer and more homogeneous castings, and that the iron does not shrink as ordinary castings do, but retains an elasticity due to the fine pores not being contracted, as they will be when subjected to chilling. This elasticity also prevents the metal cracking and breaking when subjected to blows and pressure. The decarbonizing linings are of such substance as bituminous coal treated with black oxide of manganese or chromate of iron to remove the sulphur, or coal and oxide of manganese may be used in combination, or the linings may be of magnetic iron and clay, charcoal or micaceous rock saturated in alum and water. The moulds thus lined are also to be heated to receive the molten steel, first decarbonized as much as can be in the refining furnace and remain fluid, which being cast, will be wholly decarbonized and produce very fine castings of the character of wrought iron, or the decarbonizing may be stopped at any point by the duration of time the moulds are allowed to remain heated, or the degree of heat to which they are subjected. Thus, it is claimed, carbon in the proper degree for either high or low grades of steel may be retained, or it may be entirely removed to make soft iron. The linings may be renewed from time to to time by washing the moulds with a solution of the decarbonizing substances in a pasty condition. The difficulty claimed in producing entirely decarbonized castings hitherto has been that the metal will not flow when decarbonized below two per cent. of carbon, while, by the above improvement, the inventor claims to have accomplished the desired result. Such is the process as described. In practice it would seem to have objections of expense in heating moulds, regulating temperature of oven and especially in preparing moulds.

Before the inventor can obtain the advantages justly to be derived from a thorough process of decarbonization, he must conduct this process in the molten metal, or during the process of melting. This is the desideratum to which the Bessemer process, the Danks mechanical puddler, and others, are directed, all moving in one direction—to eliminate carbon and avoid puddling as now conducted. A step further, or, rather backward, is, however, the true channel for inventors, in which to exercise their ingenuity. Why carbonize the metal in reduction to such an extent as to render all this subsequent decarbonizing labor necessary? In other words, reduce iron ore to the metallic state without the excess of carbon produced by the present process, and produce a malleable pig. Here is the grand objective point to be reached, and with the immense number of intelligent minds seeking it, it is not visionary to expect practical results in our day. The manufacture of steel becomes then perfectly simple, as the difficulty is not in recarbonizing, but in obtaining a homogeneous metal for the purpose.

The true route to malleable castings and cheap steel is through the blast furnace, and not in doctoring its product subsequently. The Bessemer product is not of a character to be classed as steel further than in its strength and hardness. It can not be tempered, and will not weld without great difficulty. This proves that the decarbonizing of an over carbonized metal, and the subsequent addition of the percentage of carbon named for steel, will not produce that metal. So of many of the other conversions before the market, scarcely one of them presents the real requisites of steel.

Thus, when we shall have produced a metal from the ore which shall be freed from the impurities of sulphur, phosphorus and silicon, and not contaminated with carbon, either graphitic or combined, we shall have reached the true malleable pig, and in the same process produce the steel pig by a simple change in manipulation of the burden in the furnace.

Meanwhile the foregoing processes offer many advantages for the production of small steel castings.

There are in America and Europe more than 250 manufactories of india-rubber articles, employing some 500 operatives each, and comsuming more than 20,000,000 lbs. of gum per year.

RAILWAYS IN TURKEY.

From "The Engineer."

There is no longer any doubt that the railway system is going on in earnest in Turkey. The great Roumelian line is being prosecuted at several points. From Constantinople the short line which is opened is being continued towards Adrianople. The mistake has, however, been made of constructing first the branch line from Adrianople to the sea at Dede Agliaj, while the necessary port at this new point is not being made, so that it will do little good for the export of produce or the transmission of passengers. Undoubtedly, the whole resources should have been devoted to the prosecution of the main Roumelian line connecting Adrianople and Constantinople with the European system. The suspicion has naturally been excited that the Dede Agliaj line, being in easy country, has been pushed on to allow the contractors to draw a mileage rate. Beyond Adrianople the works of the main line are, however, going on to Filibeh or Philipopolis, a most important section. On all the works the engineers are chiefly Austrians, and among the sub-contractors are some English and French—a nice reversal of conditions, which is owing to the dissatisfaction caused by the proceedings of the English companies under Turkish auspices. In Constantinople most of the land and house property has been appropriated for the intramural line and great terminus, including 1,000 houses, and the works will be shortly proceeded with. It will have a wharf in deep water. The materials for the new floating bridge over the Horn, under French auspices, are on the spot. The only works partially under English auspices are a tramway on the Pera side to Bebek, now open, and a road to the upper Bosphorus. Constantinople has now become a centre of engineering activity, under the inspiration of the Sultan and the direction of an energetic Minister of Public Works, lately reappointed, Edhem Pasha. In mechanical engineering the English hold their own at Constantinople. Chiefs and workmen are actively engaged in the dockyard and arsenal, where large operations are carried out. The English workman has kept up the national character, which has not been so successfully maintained by the larger operators. The ports of Kustenji and Varna are not pushed with the requisite vigor and means. At Salonica extensive wharfage is being carried out in connection with town improvements and the removal of the old walls. On the Asiatic side Government is engaged in a new experiment, that of beginning the first section of the Asiatic railway in connection with the great Indo-European line through Constantinople. The Government, having been unfortunate in its concession of the Asiatic line, and being indisposed to engage at the other end in a Euphrates Valley line, which is of no immediate interest to them, particularly since the opening of the Suez Canal, are devoting some small means to the Scutari end. Military labor will be employed and every resource made available. The line has been objected to as being parallel with a steamboat route, but it is indispensable for the through line. This was a concession to Mr. James Landen, who spent a large sum on the surveys. The whole line to Bagdad is said to be embraced in the new financial combination called Lord Dalling's Company (Sir Henry Bulwer's). Meanwhile the works are being actively pushed on, and rails will soon be laid. By bringing Constantinople to bear on the interior districts, a real impulse will be given to the main line.

THE TEMPERATURE AND ELASTICITY OF STEAM.

By Mr. ALEXANDER MORTON.

From "The Artizan."

The early experimenters on steam, and other physicists since their time, have cherished the hope that some simple law would be found to connect the temperature, pressure, and density of steam, and as the subject had occupied much of the writer's time, he would now lay before them some results of his labors.

Until the publication of those beautifully accurate experiments of M. V. Regnault on the temperature and elasticity of steam, we were without a chart to guide us. Those experiments were intrusted to him at the expense and by order of the French Government (published in the Memoires de l' Académie des Sciences," 1847), and are now well known to be the standard upon which mathematicians have labored to find some simple formulæ which would include their whole range.

When such physicists as Gay Lussac, M. Biot, and M. Regnault, including, also, some of our greatest mathematicians, have devoted so much of their time to this subject, its importance need not be questioned. From some experiments of the writer, and others which he had studied, he had been, so to speak, impelled to attempt this problem, and he had now adopted a formula and deduced his constants from M. Regnault's experiments, so satisfactory to himself, that he had prepared the annexed table to show the comparison between the formulæ and the "graphic curve" M. Regnault had given, and he hoped to be excused if, in pointing out the differences between his formulæ and those of others, he should inadvertently appear to undervalue their labors.

In calculating that table which M. Regnault has added as a summary of his experiments throughout their whole range, he found it necessary to make use of three distinct formulæ, neither of which could, with any degree of accuracy, be extended beyond the limits fixed by him. The first being from 32 deg. below Centrigrade zero to 0 deg,, or freezing point; the second from 0 deg. to 100 deg., or boiling point; and the third from 100 deg. to 230 deg. The third or last formula he terms "the unique formula" (H), and when compared with the "graphic curve" at the higher temperatures it is certainly very near ; but at the freezing point and other low temperatures the difference of the logarithms is too great to warrant us in admitting such errors could have been overlooked by an experimenter of his experience and knowledge ; hence the necessity for three distinct formulæ ; moreover, these formulæ are not more simple than many which have been published since.

The most accurate formula, enclosing the whole range of the curve, was published fully 20 years ago in the "Edinburgh New Philosophical Journal" for July, 1849, and from that time to the present the writer was not aware of any since published that could at all compare with it, either for range or accuracy. This formula had been suggested to its author by our esteemed ex-president, Professor W. J. Macquorn Rankine, from his theoretical views on the action of heat ; but that it is an absolute expression of the law, its deviation from the experiments at the lower temperatures leaves room for question.

Messrs. Fairbairn and Tate, in or about the year 1859, made a series of experiments with some very perfect experimental apparatus, with the view of determining the law of the density and expansion of steam, which formed the subject of a paper read at the British Association Meeting of that year ; but these experiments having been subsequently extended and developed by these gentlemen, a full report was not made public until after the "Bakerian Lecture," May, 1862. In studying these experiments, and whilst comparing them with some he had made himself, with the view of defining the density of steam, the formula now under consideration, connecting the temperature and elasticity of steam, suggested itself to him, and to give them an idea of its accuracy he had prepared the large sheet now exhibited.

The first two columns give the temperatures in Cent. and Fahr. degrees, from—32 deg. to 230 deg. Cent. The third column gives the pressure in lbs. per sq. in. deduced from M. Regnault's "graphic curve" which is given by him in millimetres. The fourth column, also in lbs. per sq. in., has been calculated by the formula for the purpose of ready comparison. The fifth and sixth columns give the corresponding logarithms. He had added the last two columns in millimetres to show the differences more fully. Those pressures below the freezing point are copied from M. Regnault's summary table, and those above that point are copied from his table for the air thermometer, series H, page 608.

At—32 deg. Cent. the pressure 0.320 millimetres is the lowest experimental point upon which he founds his first formula ; at that point the formula under consideration gives 0.319 millimetres, differing only the one-thousandth of a millimetre. At the freezing point the difference becomes about one-seventieth of a millimetre ; at the boiling point about $\frac{1}{3}$

of a millimetre; and at 210 deg. Cent. or 410 deg. Fahr., the difference is only 6 millimetres in upwards of 14,000.

The intermediate stages are equally near, often nearer, and as the formula by logarithms becomes simple addition and subtraction, he trusted both formula and table might be found useful hereafter. One very important element in this formula is the first term of the denominator ($\sqrt{tt}$), which expresses that the square root of the temperature is multiplied by the temperature itself. The form of the expression as explained by Professor Rankine and others, is that which was adopted by Professor Ro he, and differs greatly from that adopted by M. Biot and M. Regnault. It is much more simple, and this fact commends itself. Of all the formulæ which have been from time to time proposed, he thought he had for the first time multiplied the square root of the temperature by the temperature itself, and he begged particular attention to that term. The zero points and constants which he had adopted were calculated to the best of his judgment from the standard experiments before named, and when the many corrections for different kinds of glass, pressure on the bulbs of the thermometers, etc., are taken into consideration, necessary in such delicate experiments, it is surprising how well they agree with the formula. For instance, at 250.0 deg.; Cent. by the standard air thermometer, Choisy le Roy crystal gave 253.00 deg ; ordinary glass gave 250.05 deg.; green glass gave 251.85 deg.; and Swedish glass gave 251.44 deg. There is another point to which he would direct attention ; in the experiments tabulated by M. Regnault, those performed with the air thermometer, and those with the mercurial thermometer, agree exactly with—32 deg. Cent. to the boiling point ; but from that point upwards the pressure registered by the mercurial thermometer gradually declines until at the highest temperature, 230 deg. Cent.,or 446 deg. Fahr., the pressure registered is 20160.0 millimetres, whilst the air thermometer for the same temperature registers 20915.0 millimetres. Now, near as his formula agrees with the air thermometer experiments, unlike all other formulæ heretofore proposed, at the highest experimental temperature it gives a less pressure than that by the air thermometer, and a greater pressure than that indicated by the mercurial thermometer; whereas all other formulæ at that temperature give a greater pressure than that indicated by either the air or mercurial thermometer, and this is a very important difference, more especially if the formulæ be applied to higher temperatures than those of experiment.

Near the beginning of this paper I stated that M. Regnault, before being able to construct his general table, had necessarily to make use of three different formulæ. The three points of the curve given by experiment he chose for a basis for his first formulæ were—32 deg.,—16 deg., and 0 deg. Cent. Thus :

Temperature. Centigrade	Experiments. Millimetres.	Formula. Millimetres.	Difference. Millimetres.
—32	0.320	0.319	— 0.001
—16	1 290	1 326	+ 0.036
0	4.600	4.586	— 0.014

For the second formula experimental constants chosen by him were thus:

Temperature. Centigrade.	Experiments. Millimetres.	Formula. Millimetres.	Difference. Millimetres.
0	4.600	4.586	— 0.014
+25	23.550	23.695	+ 0.065
50	91.989	92.210	+ 0.230
75	288.500	288.391	— 0 109
100	760.000	759.620	— 0.380

His third, or, as he terms it, "the unique formula (H)," is given in his summary table before referred to. This formula embraces the greatest range of the "graphic curve," fixed by experiment, and at the higher temperatures is certainly very near it; but when used in calculating the lower temperatures; as he had already explained, its deviation from the experiments is too great to come within the limits of error. For instance, at the freezing point it gives 4.48 millimetres pressure. Professor Rankine's formula gives 4.47 millimetres, whereas, by experiment, the pressure is 4.600 millimetres.

$$\text{Log. } P = A - \frac{B}{\sqrt{t}\,t - at^2}$$

Value of the Constants.

$A = 6.0962000$

$B = 60962.00$ Log. $= 4.7850592.$

$a = 0.012884$ " $= 2.1100507.$

$t = 495.4°$ plus temperature in degs. Fahrenheit. or 527.4° below the freezing point.

TEMPERATURE AND PRESSURE OF STEAM.

Comparison of M. V. Regnault's "Graphic Curve" with the Formula,

$$\text{Log. } P = A - \frac{B}{\sqrt{t\,t - a\,t^2}}.$$

Temperature.		Pressure in Lbs. per Square Inch.		Logarithms of the Pressure in Lbs. per Square In.		Pressure in Millimetres.		
Cent.	Fahr.	Graphic curve	Formula.	Graphic curve	Formula.	Graphic curve	Formula.	
						m.m.	m.m	
—32	—25.6	0 00618	0.00616	$\bar{3}$.7915320	$\bar{3}$ 7898443	0.320	0.319	—
30	22	0.00746	0.00745	$\bar{3}$.8729693	$\bar{3}$ 8722283	0.386	0.385	—
25	13	0 01170	0.01179	$\bar{2}$ 0681376	$\bar{2}$.0717278	0.605	0,610	+
20	4	0 01792	0 01830	$\bar{2}$.2534617	$\bar{2}$ 2624613	0.927	0.946	+
15	+5	0.02707	0.02786	$\bar{2}$ 4325100	$\bar{2}$ 4449631	1.400	1.441	+
10	14	0.0405	0 0416	$\bar{2}$.6071512	$\bar{2}$.6197339	2.093	2.154	+
5	23	0.0602	0.0612	$\bar{2}$.7795611	$\bar{2}$ 7872300	3.113	3.168	+
0	32	0.0889	0.0887	$\bar{2}$.9491398	$\bar{2}$.9478656	4.600	4.586	—
+10	50	0.1771	0.1779	$\bar{1}$.2485775	$\bar{1}$.2501297	9.165	9.199	+
20	68	0.3663	0.3383	$\bar{1}$ 5266816	$\bar{1}$.5293209	17.39	17.49	+
30	86	0.6101	0.6135	$\bar{1}$.7853814	$\bar{1}$.7878696	31 55	31.73	+
40	104	1.0618	1.0664	0.0260334	0.0279153	54.91	55.15	+
50	122	1.7786	1 7830	0.2500754	0.2511622	91.98	92 21	+
60	140	2.8771	2 8797	0.4589557	0.4593577	148.79	148 92	+
70	158	4.5072	4 5067	0.6539056	0.6538550	233.09	233 06	—
80	176	6.8575	6 8534	0.8361697	0.8359048	354 64	354.42	—
90	194	10 1604	10.1532	1.0069134	1.0066047	525.45	525 08	—
100	212	14.6959	14.6884	1.1671956	1.1669739	760 00	759 62	—
110	230	20.7618	20.7879	1.3172650	1 3178109	1073 70	1075.15	+
120	248	28.7923	28 8330	1 4592767	1.4598900	1489.00	1491.10	+
130	266	39.2341	39 2626	1.5936640	1 5939794	2029 00	2030.47	+
140	284	52.4362	52.5628	1 7196318	1.7206788	2713.00	2718.29	+
150	302	69 0706	69 2705	1.8392935	1.8405186	3572 00	3582.33	+
160	320	89.8575	89.9697	1.9535547	1.9540962	4647 00	4652.69	+
170	338	115.2466	115.2882	2.0616283	2.0617852	5960.00	5962 15	+
180	356	145.8953	145.8927	2.1640412	2.1640333	7545 00	7544 86	—
190	374	182.3062	182 4842	2.2608016	2.2612254	9428.00	9437 20	+
200	392	225.4657	225.7875	2.3530806	2.3537000	11660 00	11676 64	+
210	410	276.6692	276.5535	2.4419609	2.4417790	14308.00	14302.00	—
220	428	336.2650	335.5470	2.5266816	2.5257533	17390.00	17352.87	—
230	446	404.4268	403.5310	2.6068399	2.6058768	20915.00	20868.67	—

Now, from what we know of M. Regnault as an experimenter, and consider the means at his command throughout the numerous experiments he has made at this temperature with mercury, and the different kinds of glass, whose corrections he must have known very exactly, it is next to impossible that he could have erred to the extent of 0.12 or about $\frac{1}{8}$th of a millimetre at the freezing point. At this point, above all others, every thing is in favor of correct indications, and that his best formula (H) gave so manifest an error at this point (and at lower temperatures gave still greater errors) is proved by his adopting special formulæ for different parts of the curve, and only using formula (H) for temperatures above the boiling point. In each formula above and below the freezing point M. Regnault takes 4.600 millimetres as his standard. He had therefore arranged his constants so that the pressure at this point becomes 4.586 millimetres, being only 0.014, or about $\frac{1}{70}$th of a millimetre less than that given by experiment, and he had done so because the pressure at—10 deg. Cent. below, and+10 deg. Cent. above that point is greater by the formula than that by experiment; but at these points, and (with the exception of the boiling point) all othe points where the indications of the thermometer are absolutely necessary, the chances of error, he considered, become increased.

In concluding, the author would have it understood that he did not say this equation was an absolute expression of the law; but being a simple formula, embracing the whole range of the "graphic curve," and coming so very near it, from the lowest to the highest temperatures, he thought the absolute expression might be questioned, and probably a step made in the right direction.

He annexed the values of the constants, and in converting pounds per sq. in. into millimetres, he used the logarithm 1.71361-80. For inches of mercury, 0.3087835. Specific gravity of mercury at the freezing point at Paris, 13.29593.

INDIAN ENGINEERING AND INDIAN RIVERS.

From "Engineering."

One of the greatest difficulties that has beset our engineers in India has ever been the uncertainty of the rivers. Sometimes this uncertainty has been with reference to the river channel which, in certain cases, is liable to change its course from time to time, and instances have been known of a bridge which once spanned a river bed, being left high and dry, whilst the river, divesting itself of the encumbrance, ran freely past it on one side. But a more serious, and also a more common danger to engineers and their works is the occasional occurrence of exceptional floods of irresistible force—which, finding too little waterway allowed for their swollen torrents, breach embankments, and carry away bridges as though they had been things of straw. For such events the engineer is not always to blame. There are, in most cases, no records in existence relative to the height of floods in certain rivers extending back to any great distance, and in such instances it is the usual custom to make inquiries of "the oldest inhabitant" living in the neighborhood of a proposed bridge, as to the level of the highest known flood, which is generally remembered by the fact that on one occasion the water reached the door sill of a certain hut, or extended to such a distance beyond a certain landmark; but beyond such questionable authorities there is little left to guide him in this most important investigation, and he has accordingly to make the best of such "proofs," and to make such provision for waterway as may seem necessary to meet the requirements of probable extreme floods of the future. After the construction of such works, however, improvements in the upper beds of a channel, and the removal of obstructions, may cause such increased facilities for the flow of floods as seriously to compromise any works lower down stream, and even the clearance of forest may, by removing one of the barriers imposed by Nature for preventing the too rapid flow of excessive rainfall on the catchment basin of a stream, into the natural drainage channel, cause such a disturbance of the relative proportions of river-bed to the drainage area, as to stultify all previous calculations relative to the flow of water which it may be called upon to accommodate. Owing to the so-called "unprecedented" rains of this year in the Punjab, most disastrous effects have been produced upon some of the works on the Punjab and Delhi Railway, and as this is a subject which, above all others, perhaps, is most important to be considered in the construction of river works in India, we have thought it desirable to draw prominent attention to it on the present occasion, and, in doing so, it is not with any desire to reflect upon the want of forethought on the part of the engineers of that railway, but rather to draw special attention to a fact which, though now well known, is perhaps not sufficiently thought of and allowed for in the construction of those works, which must ever prove the weakest points of a railway, especially in India, namely, the bridging of rivers.

From Delhi to Moultan the railway passes over a country almost perfectly level, the exceptions being an almost imperceptible rise in the ground between the rivers, and the low broad beds of the rivers themselves. Between Delhi and Lahore the line crosses three great rivers, the Jumna, the Sutledge, and the Beas, besides a great number of smaller rivers, such as the Gugger, the Tengri, the Kalee Nuddee, and several large canals. Over the level country the railway is carried on a raised embankment, here and there pierced with culverts to give waterway to the periodical floods, and this embankment runs directly across the natural runs of the drainage. The embankment thus acts as a great dam, and when rain falls in too great quantities to admit of being carried off by the river beds, or the culverts, the country becomes flooded, and the surplus water is heaped up on one side of the dam, which must inevitably give way if it be not strong enough to resist the enormous weight, or become breached should the water at any one point overtop the summit of the embankment, or the culverts may be blown up by the force of the water, resulting in either case in the destruction of a portion of the railway. The flooding of a considerable tract of country may also, besides the destructive consequences above named, be followed by evils not less to be dreaded, upon the subsidence of the waters, namely, such as arise from malarious exhalations. And it is not altogether unreasonable to suppose that the complaints on these grounds, raised by the natives in Lower Bengal some time back, may have had good foundation. They pointed out the injurious effects caused to the surrounding country, from a sanitary point of view, by the embankments of the East Indian Railway, which, they asserted, by interfering with the proper drainage of the country, caused an increase of swamps and their usual malarious effects. Across the rivers the Punjab Railway is carried by means of girder bridges built upon piers, the piers being sunk on single wells. The Punjab rivers are noted for the shifting character of their course, and sometimes, without any apparent reason, a river will suddenly begin to bear against some particular point, and in the course of one season change its bed to the distance of perhaps several miles. Bridging these shifting rivers, therefore, is a difficult task, involving also, as it does, the responsibility of selecting some spot where, from local circumstances, such a deviation of channel is not possible to occur. Such immense bridges as those over the Sutledge and Beas may fairly be considered as great engineering triumphs, having been constructed in spite of great natural difficulties, one of the chief of which was the obtaining of a sold foundation for the piers; for on sinking to a certain depth in the river bed, quicksands of a peculiarly shifting nature were invariably encountered. Indeed, it is stated in a recent local report, that underneath the bed of every Punjab river there is an underground river of water and sand corresponding to the course of the external river.

The foregoing particulars and considerations will, in some measure, assist in accounting for the serious failures which have recently taken place on this railway upon the occurrence of an unusually high flood. The disaster itself, also, will not be an unmixed evil ; for failures of great engineering works, not arising from the use of inferior materials in construction, or from recognized errors in design, are often the dearly bought experience which ultimately leads to improved knowledge; and although such a method of obtaining knowledge is to be deprecated, it is nevertheless through accidents and fortuitous circumstances that many great discoveries and inventions have been made. Instead, therefore, of merely lamenting over a serious accident, or endeavoring to discover who shall be hung, the searcher after knowledge and truth will always endeavor to turn the occurrence to his advantage, and by making a faithful examination into the cause, learn how to avoid similar catastrophes for the future. Let us hope that the present lesson will not be altogether lost on the railway engineers in India, and that the numerous State lines, which have been so long talked about, if ever they are really commenced, and actually prosecuted to completion, may be found provided with every safeguard against accidents from floods, and other natural causes, which the experience of the past has proved to fall, as a rule, to the common lot of such works in India. To return to the recent accident on the Punjab and Delhi line. From accounts from India it would appear that the floods of the past season have not only damaged the embankments of this line, but the bridges have also suffered to such an extent that the traffic is virtually stopped, and it remains yet to ascertain the length of time and amount of expenditure that will be required to be expended before the line can be put again into proper working order. Amongst other calamities, the Beas bridge is broken. One pier has sunk, carrying with it the girders on each side. The defence wall, built to protect the junction of the bridge with the ordinary embankment, has been broken down, and a huge gap made in the embankment, through which the river is now rushing, as if in a new channel, over the engine which lately sunk into the gap. This, it is supposed, was caused by one of those circumstances referred to above, as being common to some of the Punjab rivers; and the river Beas, in seeking a new course towards the east, and so unduly pressing against that side abutment, caused the accident which we have now to record. The pressure in that direction appears also not to have slackened since the occurrence of the mishap, and now the embankment has been so damaged between the bank of the river and the Kurtarpore station, nine miles off, that traffic has been stopped. Between Kurtarpore and Phillour, on the banks of the Sutledge, the pressure of water has not been so great upon the embankment, but the bridge across the Sutledge is considered doubtful, and no trains are permitted at present to run over it. The eastern side of the Sutledge has been damaged, and the embankment is said to show signs of giving way. At Rajpoora the embankment has received some damage, and the bridge over the Gugger is broken. The rail is carried over this river by a girder bridge on piers, like the other great bridges. One of the piers has given way, and falling on the down stream direction, carried with it the span girders on each side. There had been exceedingly heavy rain during the night, causing the Gugger to rise 16 in., the force of which proved more than the bridge was able to withstand. Between Umballah and Sirsawa, the embankment is much damaged, and it is reported that one or two bridges over the smaller rivers have either given way, or are showing signs of weakness.

Such is the list of disasters caused to a single line of railway by a single flood, so far as the record of them has at present reached us. Of course there will be the usual commission appointed to examine into the cause of this calamity, and we shall look forward with considerable interest to the appearance of their report, which, it is to be hoped, will not be confined to a mere narration of the fact that an unusually high flood caused an unusual amount of damage to the railway, for which no one can be held responsible; but that some useful deductions may be drawn from the circumstances of the case, which may prove instructive to engineers generally, and especially to those who may be engaged upon the preparation of designs for future railways, or for the execution of such works as will be required for the repair of the line in question.

The "Shipping and Mercantile Gazette" mentions that the recent struggle between the Great Northern and Midland Railways regarding the coal traffic has led to a movement in the north to revive the sea-borne coal trade, by means of screw colliers of a greatly increased size, and on a new principle, by which it is believed supplies may be sent to London at some shillings per ton below the price at which they can be delivered by any railway lines.

MAXIMUM VELOCITY OF METEORIC STONES REACHING THE SURFACE OF THE EARTH.

From "Nature."

In Prof. Nordenskjold's account of the Aerolitic Shower which took place near Hessle, in Sweden, on the 1st of January, 1869, he mentions as a remarkable fact, that stones weighing 2 lbs., which struck the ice of the Larsta-Viken, failed to penetrate, making holes only 3 or 4 in. deep in the ice and rebounding. (Vide the "Academy," Dec. 15, 1870.)

The small velocity retained by these stones, at the time of striking the earth is, doubtless, owing to the resistance of the air, and, consequently, is not an indication of the velocity which they had upon entering the atmosphere.

Stones thus penetrating the atmosphere from interplanetary space, would be moving in a resisting medium under the joint influence of their original velocity of translation and the constant action of terrestrial gravity. In the case of small masses, the resistance of the medium would very speedily produce retarded motion; and before traversing 20 or 30 miles of air, they would probably move with a velocity approximating uniformity, and under the action of gravity alone. In other words, they would gradually lose their original velocity of translation, and, descending, nearly or quite vertically, under the action of gravity, would ultimately attain a maximum velocity under the opposing influences of the resisting and accelerating forces, and then descend to the earth with this uniform velocity.

Thus, for example, a rifle bullet shot obliquely into deep water, would very soon lose the horizontal component of its velocity, while the vertical motion would be so rapidly retarded that, at a comparatively short distance below the surface of the water, it would begin to descend vertically with the very moderate uniform motion resulting from the resistance of the liquid and the constant action of gravity.

In like manner, no matter how great the velocity with which a meteoric stone enters the atmosphere, the enormous resistance which it encounters must operate ultimately to produce a similar result, although, in some cases of oblique incidence, the horizontal component of velocity is not entirely lost before reaching the earth.

It is well-known that this maximum or limiting velocity of a falling body is attained when the required velocity is such that the resistance is at each instant equal to the weight of the moving body. In the case of small masses moving in the air, it may be shown that this velocity is quite moderate.

The principles of dynamics furnish the means of determining the resistance of a given body moving in a medium of a given density when the size of the body and its velocity are known.

Let A = area of cross-section of body at right angles to direction of motion.
D = weight of unit volume of medium (air).
v = velocity of moving body (meteoric stone).
g = acceleration by gravity in a unit of time.
k = a constant co-efficient, deduced from experiment, depending upon the shape of the moving body.

Then we have,

$$\text{Resistance} = k \times A \times D \times \frac{v^2}{2g}.$$

Hence, by the conditions under which, as above given, v becomes a maximum, if w = weight of moving body or stone, we have,

$$k \times A \times D \times \frac{v^2}{2g} = w \therefore v = \sqrt{\frac{2g \times w}{k \times A \times D}} \quad (a.)$$

Applying this formula (a) to the case of a meteoric stone weighing 2 lbs., moving in the air:—let us assume it to be a cubical mass, having a specific gravity of 3 in relation to water as unity. Then its volume = 18.482 cub. in., and the area of one of its faces = 6.9903 sq. in. = 0.048544 sq. ft. Hence, assuming the resistance to act at right angles to the face of the cube, and taking the pound and foot as units, we have

A = 0.048544 sq. ft.
D = 0.0807288 pounds = weight of cubic foot of air at 0° C.
w = 2 lbs. weight of stone.
g = 32.1928 ft. per sec.
v = required maximum velocity in feet per second.

Hence, by formula (a).

$$v = \sqrt{\frac{2 \times 32.1928 \times 2}{k \times 0.048544 \times 0.0807288}} = \sqrt{\frac{128.77}{k \times 0.0039189}}$$

$$= \sqrt{\frac{32859}{k}}.$$

Or, $v = \frac{181.27}{\sqrt{k}}$ in feet per second.

Assuming $k = 1.3$,* we obtain,

$$v = 158.99\ (= 159)\ \text{ft. per}$$

second, as a maximum velocity attained by such a stone in falling to the earth. This velocity does not exceed one-tenth of the initial velocity of a rifle bullet. And, as the penetrating power of a given projectile is proportional to the square of its velocity, its power of penetrating the ice would only be one-hundredth part as great as that of a projectile of similar mass and dimensions moving at the rate of a rifle bullet. Hence we need not be surprised that the ice was not penetrated more than 3 or 4 inches.

If the same mass of stone (2 lbs.) were spherical in form instead of cubical, its diameter would be 3.2803 in. = 0.27336 ft., and A = 0.058689 sq. ft. In this case, we may assume $k = 0.7$.† Hence. by the formula (a) we obtain,

$$v = 197.05 \text{ ft. per second:}$$

so that in this case likewise its velocity would be quite low, and its penetrating power very insignificant.

Of course, in the case of large meteoric stones the value of v would be greater.

* For cubes moving in water the experiments of Du Buat and Duchemin give $k = 1.280$.

† For spheres moving in air the experiments of Robbins and Hutton give for velocities:
$v = 3.28, 16.4, 82, 328$ ft. per sec.
$k = 0.59, 0.63, 0.67, 0.71$.

THE BROAD AND NARROW GAUGE FOR RAILWAYS.

The assertion has been so often made that a broad gauge railroad, although possessing points of superiority over the narrow gauge, is on the whole inferior, and costs very much more than a narrow gauge road, that a correct statement of the case is demanded for the information of the public.

By the broad gauge road, is supposed a road like the Erie (late the New York & Erie), the track of which is 6 ft. wide; that is, it is 6 ft. in the clear between the two rails of the track; and by the narrow gauge a road having a width of track of 4 ft. 8½ in., or 4 7-10ths ft. in the clear between the rails. In England, the term "broad gauge" means a gauge or width of 7 ft. No such gauge has been adopted or recommended for any railroad in the United States. More recently a narrower track than 4 7-10ths ft., that is, a track 3 to 3½ ft., has been advocated as suitable for railways in certain localities. These, it is probable, will not assume importance enough to be considered in a general scheme for railway transit, and hence will not be discussed in this investigation.

The rails of a railway designed for general traffic and travel, and for the use of locomotive steam power, are formed usually of iron. They weigh from 56 lbs. to 80 lbs. per lineal yard, and are connected by joints of the same material. The rails are spiked or fastened by their lower web to cross sleepers of wood, which serve as supports, and as ties to keep the rails at a uniform and proper distance apart.

To arrive at the correct relative cost of a 4 7-10ths ft. and 6 ft. gauge, the same plan of construction should be assumed for both, and the items in each considered separately, and their value carefully estimated.

The comparison should be made free from prejudice, and free also from any interest, direct or indirect, in the numerous establishments for engine and car building in the country.

If timber ties or sleepers of the same number and quality are used for both gauges, those of the broad gauge will cost the most because of their greater length. The two gauges differ in width 1 3-10ths ft.

Ties for the narrow track are are usually made 8 ft. in length. For the broad track they should, therefore, be at least 8+1 3-10ths or 9 3-10ths ft. or about 1-6th longer. This additional length will cost, probably, about 1-5th more.

If, therefore, narrow gauge ties can be obtained, delivered on the line of the road where used, for 50 cents each, which is, probably, above their average cost, the broad gauge ties should cost 60 cents each; and if the usual number of 2,340 per mile are used in both cases, the additional cost per mile of the timber ties on the broad gauge will be 2340×10 or $234. The ballast will also cost more, and about in the same proportion as the ties, or about $180 per mile more, making a difference in both items of 234+180 or $414 per mile in favor of the narrow gauge in the cost of superstructure for a single track, the labor of putting the rails in place being supposed the same in both cases.

There is also a difference in the same direction in the cost of the equipment, or the rolling stock, in the greater length of the four axles and greater width of the truck frames of each car, equal to about $60 to each eight-wheel car, and $140 to each locomotive and tender. This assumes that outside bearings are adopted on the broad gauge, which is not customary; with inside bearings the cost of the cars is not increased.

A railway when properly equipped for doing a very good business requires 1 locomotive for each 3 miles of road, and 6 eight-wheel freight and passenger cars, and 1 four-wheel gravel car for each mile of road, making the extra cost per mile for equipment on the broad gauge about $440 per mile with outside bearings, and not over $50 per mile with inside bearings. This increased cost is more than counterbalanced by the less weight needed for the rails and the wheels on the broad gauge to render them equally serviceable and strong with those of the narrow one.

This less weight is determined by the greater strain to which the rails and the wheels of the narrow gauge are subjected when the rails are not properly adjusted, as is frequently the case, a strain at times much increased by the lateral force of the wind.

The entire force thus acting to injure or fracture a rail or wheel by the lurching caused by a depression of a given depth in either rail, is full 15 per cent. the greatest on the narrow gauge. Assuming one-tenth to be saved in the weight of the wheels and rails, which is a moderate estimate, and estimating 5 cents per lb. for the former and $90 per ton for the latter, the saving amounts to $1,000 per mile for a single track, and twice that for a double one; an amount which exceeds the cost of the items for longer ties, ballasting, etc., as above stated, for the broad gauge. Keeping in mind, therefore, that the question of gauge is alone being considered, and that the equipment is to be no heavier on the broad than on the narrow gauge, it will be found on a fair estimate of the relief afforded to the wheels and rails, and other advantages by using the broad gauge, that the whole will exceed the sum total of the items in which the broad exceeds the narrow gauge in first cost.

It is not easy to arrive at the precise difference of the two in figures. Of the other advantages, it is easy to understand that the broad gauge, because of its wider base, gives a more steady movement to the train, and there will be less of that irregular sideway or lurching movement which tends to strain and wrench and weaken the bodies and frames of the cars, and the machinery of the engines, and which is a principal cause of the depreciation of the rolling stock on all of our railroads. There can be no doubt that a steadier and more equable movement of the trains will result in less injury to the road and its equipments, less cost of repairs, and more effect to the motive power.

To assume that the cars and engines, because of this less wear and tear, will last one year in twenty longer, is believed to be a moderate estimate; and one-twentieth part of the cost of equipment per mile average, is about $1,000. To this should be added another large item that cannot easily be estimated, in the increased revenue from its superiority over competing lines on the narrow gauge, by giving increased comfort and safety to travellers. There are some other items of cost in making the comparison, which it is proper to consider. A writer in a prominent New York daily, the "N. Y. Tribune," not very long since made this declaration that, "on a broad gauge road it is clear enough that in the first place, the original outlay in the cost of the road is much greater than on a narrow gauge road." That, "at the outset the right of way costs more, and the road bed costs more, the bridges cost more, everything, in short, costs more."

Such assertions are not sustained by the facts or by sound argument, and are positively injurious and criminally so, as their tendency is to mislead on a subject of the greatest importance to the public and the owners of our railways. As to the right of way costing more, the absurdity of the assumption is obvious when it is considered that the narrowest of the narrow gauge cars is more than 3 ft. wider than the broad gauge track. Hence, wherever a narrow gauge car can run there is abundance of room, or right of way, for laying a broad track, and no additional right of way is required. As to the road-bed, 15 ft. is the customary width of the road-bed for a single track on the narrow gauge, but even if it be from 2 to 4 or 5 ft. less, giving a width of only 10 ft., as is sometimes the case on second and third class roads, it still can support a 6-ft. or broad gauge track. The track being double does not alter the case. The space between the tracks is governed by the width of the cars, which is assumed the same for both gauges. The width of road-bed regulates, of course, the length of the culverts, the amount of masonry in them, and their cost.

The cost of a culvert of masonry is made up in a large measure in the cost of the end and wing walls, which is the same on either gauge for the same opening or water-way. To lengthen the body of a culvert of medium size, say 4 ft. chord, to the extent of 1 3-10ths ft. (the difference in the width of the gauges), will require not more than 2 cubic yards of masonry, which with the foundation will not ordinarily cost over $30 or $40. It is obvious, therefore, that the cost of the road-bed is not greatly or materially increased to adapt it to a broad gauge track.

As to the bridges, there is no difficulty in laying a track 6 ft. wide on a bridge designed to pass narrow gauge cars. The latter are never less than 8 ft. wide and passenger cars are oftener 9 to 11 ft. The bridges, therefore, not being wider, are not more costly on the broad gauge, but, on the contrary, there is some saving in cost, for the rails of the track being nearer to the vertical truss frames, the transverse beams on which they rest may be smaller, and of course lighter, and less expensive. An useless weight is thus taken from the bridge, and it is stronger for the support of the trains passing over it. Other items are not increased, such as excavation in tunnels, drainage in excavations, snow guards, and fencing, warehouses and depot buildings, labor expenses of operating the road, and fuel, the general expenses which form a large item, including salaries, office rent, etc., and what is usually also a very considerable item in the cost of roads, the interest account. All these are not increased.

It is evident, therefore, that the writer referred to is altogether wrong in his statements, and that the assertion that everything necessarily costs more on a railway having a broad gauge, has no foundation of truth to stand upon; but, if properly built, the broad gauge road will not differ greatly in cost from a narrow gauge road on the same ground, and that difference, even if in favor of the narrow gauge, which is not probable, is more than made up by the broad gauge being less expensive to operate and maintain, the wear and tear upon it being less.

A little reflection will also show that, *all other things being equal,* there must be greater security and safety, as stated, upon railways having the broad gauge, and consequently fewer broken limbs and fewer lives sacrificed, and a less amount of damage for items of this character.

As to the greater safety, it should be understood that the great injury to and wear of the rails of a railway is produced mainly by the driving or drawing wheels of the engines, which, to obtain adhesion, are loaded often with a weight of 5 to 7 tons on each wheel, a weight so great that there is very little or no *give* to the springs; and hence, if the track is at all out of adjustment, as railway tracks too often are, the wheels of the engine, in passing a depression in the rails, strike into it with a sledge-hammer force, increased in intensity just in proportion as the track is narrower, since upon such a track the sidewise or lurching action of the engine is greatest. This is a result which no well-informed mechanic will or can question, and the extra annual injury and wear to the rails and machinery on the narrow gauge from this cause alone on a road doing any considerable business, is very much greater than the interest on the particular items wherein it has been shown the broad exceeds the narrow gauge in first cost.

This is no exaggeration. The rails of the narrow gauge suffer most, and the danger is greatest of the breakage of both wheels and rails, other things being equal, as stated.

Upon the narrow gauge roads, to satisfy the requirements of the public for more comfort, and accommodation, and speed, passenger and dormitory cars are expanded to an inordinate breadth and height, as compared with the gauge, and hence are increased in weight, and made top-heavy, because of their narrow base. The increase in speed demanded by the public is only effected by increasing the dimensions of the boilers of the engines, which, to get heating surface, are made so broad as to require to be placed above the drawing wheels, thus increasing the relative height of the centre of gravity of the mass of the engine, and increasing, also, the strain upon the rails and wheels, and the wear and tear of both, and of the machinery on the narrow gauge.

These are great evils, and increasing. *Nearly all of our narrow gauge railways are burdened with an equipment better suited to a broad gauge,* but not necessary to it. This disproportion of equipment to gauge causes an amount of injury and damage to the roads and machinery, and a greater liability to accidents, which is not fully understood by railway stockholders and the public. The life of the rails is thus, beyond doubt, greatly shortened, and the fact has not come home to the consciousness of those managing the roads, as it will come in a few short years, when the great wear and tear of the roads will be made obvious in the cost of renewals and repairs. A limited period may show no very marked difference in the wear in the two cases ; but when such is the case, it is safe to assert that the attending circumstances are not equal, or otherwise it must be assumed that the laws of nature are capricious, which no sane person will dare to affirm.

There is still another consideration of importance, which should not be overlooked. When railways enter cities, as they must, changes in their direction are often so sudden, in following the streets, that the wheels upon the outer rail of a curve must bear upon their flanges, instead of their rims. To turn a given curve in this manner, the flange may be deeper upon the wheels of the broad gauge cars, and this greater depth to the flange adds to the safety of the broad gauge cars upon those portions of the road where steam is used as the moving power. There is no limit to the use of a broad gauge in a city, which does not apply to a narrow gauge as well, for the broad track of 6 ft. can be laid wherever narrow gauge cars can run, as it is narrower than the narrowest car.

The necessity, moreover, of running the cars of a train into the streets of a city, makes it also necessary to give to the city horse railroads the same width of track as other railways. Now, $4\frac{7}{10}$ ft. is too narrow a space for two horses to work in comfortably, abreast; and the inconvenience of tandem teams, as used in Baltimore and other places, in our densely populated cities, is too great to be generally allowed.

The injury to horses or mules working abreast between the rails of a narrow track is very great; one or the other is being constantly crowded on to one of the rails, which would not be the case if the gauge was 6 ft. The injury to the feet and limbs of horses from this cause alone, cannot be easily computed. It is thought to amount in New York city annually to several thousands of dollars.

It may be urged that the resistance upon the curves of the road is greater upon the broad gauge. This is true; but the difference is too small to be appreciable in the cost of operating the road. If the curved portions of a railway are assumed to average ordinarily 24 deg. of deflection to the mile (a large allowance for roads west of the Alleghanies), the difference in length of the two rails of a track on the broad gauge, for the 24 deg., is 30 in.; and on the narrow gauge it is 24 in. The difference is 6 in., which is the additional sliding for the 24 deg. on one rail of the broad gauge. A like change in direction for each mile for every 100 miles, makes the total sliding (not allowing any relief from the slightly conical form of the rims of the wheels) 50 ft. for one side or one half of the train, and only 25 ft. for the entire train, which, as an item of resistance, is less than the power usually lost by the application of the brakes in arresting the motion of a train at a single station. It is obvious from this that the increased resistance and wear of rails from curves on the broad, as compared with the narrow gauge, is too small to be seriously considered in determining the merits of the two, and will be less than it now is when steel rails are used.

The curvature upon a railway because of the straightforward tendency of bodies in motion, a tendency which is increased as the speed of the train is increased, (the wheels of a railway car being firmly fixed to the axles), adds to the danger of the engine leaving the track. The oblique manner in which the moving power acts, also, adds to the resistance, and the two constitute the total resistance nearly, and great objection to curves upon a railway. This danger and resistance is not increased by any difference in the width of the track when the curvature is the same, but at any given rate of speed the danger is really somewhat less on the broad gauge, and for the following reasons:—

1. The centre of gravity of the engine, and the cars and their loads, is relatively lower; and

2. And the flange of the wheels is deeper.

The only proper and correct mode of comparing the two gauges, is to assume, as has been done thus far, that the equipment is the same for both. There should be no difference in this respect, except what is absolutely demanded by the difference in the width of the tracks. This view, while it is necessary to a clear and just comparison of the merits of the two gauges, is not sufficiently comprehensive to embrace all of the advantages of the broad gauge, which are greater than has yet been stated. Such a gauge enables a railway company to do, *if the convenience of the public, or their own interest, requires it, what cannot be done on the narrow gauge.* The greater width or space between the wheels of the engines permits the use of boilers of larger diameter, having more heating surface, and capable of producing more steam in a given time, giving greater power and ability to attain a higher speed. The diameters of the boilers being as the gauge of the tracks, if their length is the same their heating surface will be as the square of their diameters, or as $(4.7)^2$ to $(6)^2$, or as 22 to 36 nearly, or full *sixty* per cent. the most on the broad gauge, and the power and speed of the engine may be increased accordingly.

The broad gauge does not compel the use of more powerful engines, but if such engines are needed, they can be employed, and with less wear and injury to the roads, and danger of accidents, than on the narrow gauge. If broader and higher freight and passenger cars are needed for the greater convenience and storage of freight and accommodation of passengers, they can be had on the broad gauge; but the gauge does not require that the cars should be either broader or higher. It is optional with the companies to make them so or not, and here it should be noticed, that by adding to the width of a freight car, its capacity for holding freight is increased in a somewhat greater ratio than the weight of the car or its cost. This is a gain of some importance to be credited to the broad gauge, particularly in the transport of bulky articles, such as hay, cotton, furniture, etc.

Again, if more space, and comfort, and accommodation are needed in the passenger and sleeping or drawing-room cars, they can be had to a much greater degree on the broad than upon the narrow gauge. These latter advantages, it will be seen, demand an increase in the cost. They are not essential to the broad gauge, only incidental to it, and no railway company would incur the additional cost, unless to promote its interest. They are improvements or changes which the wide gauge enables a company to make; if demanded by the public, and its own interest, and which cannot be so easily attained, or attained at all, on the narrow gauge.

In whatever light the subject is viewed, there is no escaping the conclusion of the superiority of the 6 ft. over the narrow gauge of 4 7-10 ft. for our main lines of railway.

The consideration of most weight which can be urged against the broad gauge is the inconvenience and expense of making connections with other railroads.

If such connection is demanded under circumstances which render a transfer of freight from one road to another too expensive, the difficulty may be obviated by putting down a third rail on the shorter of the connecting roads.

This third rail, if added to the wide track, involves no expense but the cost of the rail and fixtures and laying down.

If added to the narrow, the ties must be lengthened. Its cost will be so much additional capital without loss otherwise, as the wear upon two of the rails will be no greater than the entire wear upon the third, and the two rails will last twice as long as the third one ; and the profits of the road will not be appreciably lessened in the long run, while the road itself, by means of the third rail, will have more solidity and will be less liable to be disturbed by the movement of the trains over it, and maintain its adjustment better. The third rail may, moreover, prove a security or guard to a certain extent in preventing trains, when off the track, leaving the road-bed, and may be worth for this purpose as much nearly as a track with 3 rails *ultimately* costs over one with 2 rails.

It will be seen from the above that a company owning a long line of road on the broad gauge, and having occasion to make connections with other roads of the narrow gauge, can commit no greater mistake than to alter to a narrow one.

The first railway built with a 6 ft. gauge was the New York and Erie, now the Erie Railway, and that road and many of its branch connections have still that gauge. Over 30 years have elapsed since the Erie road was commenced, and only about 15 or 20 years since it was completed. The Liverpool & Manchester, or gauge of 4 7-10 ft., had then been adopted in New England and upon some other roads. The Mohawk & Hudson was then commenced with $4\frac{3}{4}$ ft. gauge. The Charleston and Augusta, Georgia, with a gauge of 5 ft. The line from New Orleans north with a gauge of $5\frac{1}{2}$ ft., and in New Jersey $4\frac{83}{100}$ ft. was adopted, and the same in Ohio, although one road in Ohio had a gauge of 5 ft., and not very long after the Canada gauge was fixed at $5\frac{1}{2}$ ft., which was the gauge subsequently adopted in Missouri. These roads had all their beginnings at points remote from each other, and it was not until the railway system had become greatly extended, and the different gauges were brought in connection, that the companies began fully to see and to realize the very great error which had been committed in not investigating thoroughly the subject of the gauge for the railways, and fixing at the earliest date upon a proper and uniform gauge for all the railroads of the country. The attention of the Erie Railroad Company was very early drawn to the subject (1836) in a formal report of their engineer, Edwin F. Johnson, and that company afterwards adopted, under the information disclosed in the investigation made (which was very thorough), the gauge of 6 ft., or what is commonly termed the broad gauge. Other companies, under a less intelligent view, blindly persisted in adhering to the accidental gauge of the Liverpool and Manchester road of 4 7-10 ft., or, with small foresight, adopted an intermediate gauge. Under this state of things the gauge which has come to to be the most common in the Northern and Middle States of the Union is that of the New York and Pennsylvania Central roads, which have the gauge of the Liverpool and Manchester of 4 7-10 ft. A gauge which was derived from the tread of the coal carts in use on the English tram-roads, and was not the result of any careful investigation as to its fitness for railways operated by steam-power under a general system, but which answered very well for Great Britain, where great speed and accommodation were not called for, the average distance travelled by passengers there not exceeding about 15 miles each on the railways.

Here, however, the circumstances were altogether different, as an entire continent, 3,000 miles broad, was to be traversed, requiring the highest speed practicable and the greatest accommodation for both freight and passengers. Even in England the gauge of 4 7-10 ft. was thought too small by many of their most intelligent men, and the line from London to Bristol was built with a gauge of *seven* ft. This alarmed the narrow gauge interest, which, like the unfortunate fox in the fable, sought to get an Act of Parliament compelling all railway companies in the country to conform their roads to the gauge of 4 7-10 ft. Parliament appointed a commission of able men to investigate and report. The commission could not pronounce against the 7-ft. gauge, even for England, but they said that if uniformity was necessary or desirable, the gauge of 4 7-10 ft. was probably the best, because most of the roads then in operation in that country, were of that gauge. The facts and evidence educed by them, and arguments advanced, mainly favored a broader gauge than 4 7-10 ft., and it is a fact, that on the gauge of 7 ft. a speed of 45 to 50 miles per hour was easily attained; but the advantage thus gained was probably in that country not equal to the inconvenience of a gauge differing from the other roads.

When a system was desired for Ireland, a territory of less extent than England, the gauge was fixed, not at 4 7-10 ft., but at *five* and *one-half feet*, and the same was subsequently adopted for the Canadas, and since for the British Indies and Australia. Our English neighbors, it would seem, had begun to realize fully the fact that a system which might answer very well for the small space covered by the "fast anchored" isle, might not be the best suited for a continent, and they were not alarmed by the denunciations of the narrow gauge interest in this country, which have been very bitter against any gauge wider than 4 7-10 ft., and have so continued to this day, to the great and lasting injury of the railway system and the best interest of the country. The railway and the steam locomotive together constitute one machine, the excellence of which depends on the proper adaptation of the one to the other, and to the work to be done. The late Zerah Colburn, the able editor of the London journal of "Engineering," in the last edition of his treatise on the locomotive (1870), after a full consideration of its powers and capabilities, thus remarks:

"It would be a matter of very great convenience were the track wider than at present [that is wider than 4 7-10 ft.], and we believe that the experience of a dozen years at most, will determine it to be a matter of absolute necessity."

This opinion of Mr. Colburn was pronounced in England, and is the more valuable from the fact that he was at first, and for a long time, an advocate of the narrow gauge of 4 7-10 ft. for railways, and challenged the writer of this to a discussion of the subject in the columns of the "American Railroad Journal," N. Y., then edited by him. The opposition to the broad gauge has, in every instance known to the writer, been easily traceable to an interested and selfish source, but it has, doubtless, in many instances, proceeded from ignorance. The wider gauge would doubtless suggest to one taking a superficial view, greater cost, both in building and in operating, and this seems to have been the case with a writer in the N. Y. "Sun" of April ult., who, after giving a very good outline history of the Erie Railroad, in which he states that it moved last year the immense number of 4,852,565 tons of freight, valued at $1,000,000,000, asks the question: how can this traffic be made to pay? A question which he answers in part (without showing that it does not pay on any reasonable cost of the road) by the statement, which is neither theoretically nor practically true, that "the exceptional gauge of the road, 6 ft., largely increases the cost of operating it."

For main lines of railway and main branch lines there cannot be any reasonable doubt of the superiority of the gauge of 6 ft. over any lesser gauge; but the question is being mooted in Europe, and beginning to attract attention in this country, whether for the remote and smaller branches, a lesser gauge of say 3 or 3½ ft., cannot be profitably used; and it will not be denied that it may be for short branches leading to mines or factories, and in sections difficult of access, where the work to be done is limited, and where rapidity of transit is a secondary consideration; but these cases will be very rare. The published statements of the advocates of these narrow roads, show an imperfect comprehension of the subject, and that there is danger of the public being misled to its injury.

Unless facts and figures both greatly deceive, the 6 ft. gauge is, as shown, decidedly superior to the 4 7-10 ft. for roads doing the work of the great railway lines of the country. A gauge of 3½ ft., such as is now being proposed in several localities, bears somewhat the same proportion to the 4 7-10 ft. as the latter does to the 6 ft. If, therefore, the 3½ ft. gauge is superior to the 4 7-10 ft. as claimed, it follows, that the latter is inferior to both the 6 and the 3½ ft., and that the country has been induced to adopt a gauge for a large majority of its roads, the least to be commended of any. The fact is, however, that a Tom Thumb road of 3 or 3½ ft. gauge is far less capable of doing the work our railways are being called upon to perform, than the 4 7-10 ft., which in turn, as has been shown, is inferior to the 6 ft. gauge, and this fact will be still more apparent when in a few more years, 30 at most, our population shall be doubled, and the exchangeable wealth of the country within its borders probably quadrupled. Our leading roads will then have work enough, and more than enough, to do, and it is not too soon for the two great lines, the New York and the Pennsylvania Central, to consider whether it is not best for them to prepare to adopt the gauge of 6 ft., and demand (for if they speak at all, they should speak now) that the Northern Pacific road, the great highway of the Continent, shall also have the same gauge.

When the building of railways was commenced from Chicago west, an effort was made to have all the railways north and west of that point of the better or Erie gauge of 6 ft., and the Chicago and North-western road, then under a different name, was commenced with that gauge in the hope that other companies would join in its use, which they declined to do, and the consequence is an inferior system of railways for the valley of the upper Mississippi. It is very unfortunate that neither the promoters of railways in that region nor their professional advisers were able to realize the importance of the plan thus recommended and commenced; and at a later date, when the granting of a subsidy to the Union Pacific Railroad Company placed it in the power of a Government cabinet officer, by a clause in the act to that effect, to fix the gauge of that road, instead of causing an investigation of the subject by the ablest men of the profession, he merely asked the opinion of 2 or 3 presidents of railway companies interested in narrow-gauge lines leading towards the Union Pacific road, and at their suggestion, it would seem, pronounced in favor of the narrow gauge. It may be that a right judgment was given in this case; but it is not creditable to the country that so important a question was in such manner disposed of, and that no proper investigation was made by competent and disinterested men of the profession.

The country is now engaged in opening another great transcontinental line to the Pacific, of far greater ultimate importance than the one now in operation.

This line (the Northern Pacific), from its position and other circumstances, is certain to be the great thoroughfare *par excellence* between the Atlantic and Pacific Oceans, and being of so great extent, and owned by one company throughout, the best gauge should and may be adopted irrespective of connections with other roads.

Notwithstanding the proven superiority of the broad over the narrow gauge, as above, it may be claimed by some that the practical operation of the only great main line, the Erie, built on that gauge, has not fulfilled the expectations formed in regard to it. This, if so, is not because the road does not possess the superiority claimed for it, but because the circumstances have been such as to prevent that superiority from becoming manifest.

Upon our main lines of railway various causes have from time to time operated to add to or lessen the revenue upon them, and the cost of working them. The Erie Railroad has been peculiarly subject to causes of this character. The period of its construction was greatly lengthened by the want of sufficient means to prosecute it, and the formidable opposition which it experienced from the more densely populated and wealthier portion of the State to the north of it, and of the country to the south of it, delayed and embarrassed its construction, and the interest account and discount on its bonds and costs were largely increased. The country traversed by it was very much of it unsettled, and time was required to bring in a population to its support. The ground also was very difficult in many places, and the work heavy and costly. The rise and fall per mile exceeded greatly that upon the northern route from New York city to the lakes by the Hudson and Mohawk valleys, etc., and the gradients were higher, and not distributed in the best manner to economize the cost of operating. The natural difficulties were greater, and artificial ones were created by injudicious management. The adaptation of the motive power and the rolling stock to the road and the gauge was not effected in the best manner, and because of frequent change in the management, and employment of incompetent superintendents, who should, in all cases, be regularly educated and trained civil engineers. This state of things, it is understood, was also aggravated by the interference of meddlesome officials, evils under which the most of our railroads are more or less laboring.

Among such a variety of causes, all of them affecting more or less the cost of operating the Erie road, it is not possible to determine with certainty, or to express by figures derived from practical results on that road, the degree or amount of benefit derived from the broad gauge. It is safe to assume, however, that it has been a benefit, and a very considerable one, and has greatly aided it in competition with other and rival lines of road.

All who have travelled upon it speak in unqualified commendation of the comfort afforded by the equable and steady movement of the cars upon it. Of the other advantages, the traveller would not be likely to be cognizant; but they must have been very great, under a fair comparison of circumstances with other lines having the narrow gauge. Some discomfort during a day's ride or so on a railway, is not of so much account to the majority of travellers; but when the journey amounts to a number of days, or of days and nights in succession, it is different, and of still greater consequence where there is competition with other similar lines of communication.

The arguments originally advanced and evidence adduced in favor of the broad over the narrow gauge, have not been disproved or refuted. The subject has undergone some investigation since, and with a similar result; but the broad gauge has not been adopted, as it would have been in many cases, for reasons which it would not be creditable to our railway managers and to the profession to state. But for this, the gauge of 6 ft. would now have been the gauge of nine-tenths of the railways of the land, and the country would have reaped a corresponding benefit.

In no part of our extensive country has there been so little excuse for an adherence to the narrow gauge, as in the region west of the Alleghanies, where the country is virtually one vast plain, and where the greatest speed, power, and comfort in the construction and operation of railways were demanded, and could easily have been attained.

Not a railway track, we repeat, should have been laid west of the Alleghanies—and certainly none west of Lake Michigan—of a less width than 6 ft.; but the causes named, and the supineness and indifference of the public, have permitted the evil of the narrow gauge to be carried far beyond that limit, and by one line, as stated, even to the Pacific.

It is fortunately not too late to prevent a similar great mistake from being made on at least two of the great transcontinental lines—the Northern and the Southern. Either of these lines is long enough, and far enough removed from any parallel lines, to be treated as independent lines, and they should be built in the best manner, and upon the most approved plan of construction; and if the broad gauge is superior to the narrow, as it has been shown to be, they should be built with that gauge.

In a comparison of the cost of road and equipment on the two gauges and other considerations, it cannot be denied that the result is favorable to the broad gauge, and the cost is only materially greater upon the latter when advantages are sought to be attained which the narrow gauge cannot furnish.

Upon the Northern Pacific Railroad the prices of the ruling items of the cost will vary in different localities, but the average cost of timber ties will be less than the amount stated above, the Company being allowed to obtain them from the public lands free of charge, while the cost of iron may be somewhat greater, leaving, however, it is believed, the balance of the cost, for the entire line, in favor of the broad gauge; but should the cost be the same, there will result a benefit in the superior character of the road, a benefit which will be realized in the saving in cost of repairs and in operating, and in the greater revenue derived from it, since the Company will be able to offer to the travelling public a means of communication superior in speed, safety and comfort, to any other, considerations of the highest importance on so long a line as 2,000 miles.

That the broad gauge should be adopted by the Northern Pacific Railroad Company, does not, it is believed, reasonably admit of a doubt, and it would be cheaply purchased by some increase in the cost, if that is necessary.

The character of the Northern Pacific road as a great highway between the two principal oceans of the globe, and between two continents where the population is the most dense, demands that locomotion upon it be rendered as perfect as possible. It cannot be made too rapid and easy, and should be effected, if to secure it, greater cost is required; but when it can be obtained at probably no greater cost, it will be a very great mistake not to obtain it.

The necessity for rapid transit is obvious from the effort made the past and present season to convey passengers between New York city and Chicago in 24 hours, or at the average speed of 40 miles per hour. Great as this need is, it is far greater for the attainment of a speed of 50 miles per hour between the two oceans.

The speed of 40 miles per hour is found to be very trying to the narrow gauge and its rolling stock, causing a rapid deterioration of both.

It will not be attempted to fix the limit beyond which there is no gain from the expansion of the gauge on the great main lines of railway. The experience in England shows that the limit is not exceeded in a width of 7 ft. and it certainly is not in a gauge of 6 ft.

The practical operation of the two gauges shows clearly a gain in speed in favor of the broad over the narrow gauge, and there is no mistake in saying that 45 or 50 miles per hour average speed on the Northern Pacific Railroad for at least one daily train each way, will justify, to obtain it, a transfer to a different gauge.

50 miles per hour is a saving of 1-5th in time over 40 miles per hour, but even a gain of half that amount may be all important in a close competition with other lines or routes, and to satisfy the requirements of commerce.

Notwithstanding what has been said of the extent of the Northern Pacific road and large surface to be covered by its branches or tributaries, all of the same gauge, it may be urged that great inconvenience and some expense will be caused by reason of connections with lines leading from the eastern portion of the road to the Atlantic seaboard.

The existing lines in this direction are mainly narrow-gauge lines. The others, omitting the 4 ft. 10 in. gauge of Ohio, are either 6 ft. or 5 1-2 ft. The Canada roads are of the latter gauge. The Erie Railroad and its branches are 6 ft. It cannot be long before the latter will be carried to Chicago, and probably, in less time than the Northern Pacific will be open to the Pacific, if improper and unwise influences do not continue to prevail against it.

From Chicago to Minnesota a third rail will be needed on the portions built, and those to be constructed may have the broad gauge at first, the third rail to be added if found expedient. The Canada roads, if changed at all, will doubtless be to the 6 ft. rather than the 4 7-10 ft., but no change will probably be made in them, if the Northern Pacific adheres to the 4 7-10 ft. Canada, in that case, will have the best line of transcontinental railway within her own borders, and the great thoroughfare of the continent may pass to the north of us, for it cannot be asserted that the ground north of lakes Huron and Superior is impracticable. It is difficult, it is true, but the superior character and facilities afforded by the Saskatchewaw valley and other portions of the route, will make amends for a vast deal that is difficult and expensive north of the lakes; and that line, as a medium of communication with Eastern Asia, will be shorter, and it will have a terminus on the Pacific, in a temperate latitude.

The Northern Pacific Company can only attain and maintain the ground of superiority by adopting the 6 ft. gauge, which it should do at once, not hesitating for a moment, because of the cost of changing the small amount of track they now have in Minnesota, from the narrow to the wider gauge. The best interest of the Company and of the country demands the change, for in this respect the two are inseparable, and if made, other lines, if they deem a conformity to the same gauge important, will also change. The New York Central, in particular, occupying, as it does, the ground between the Canada and Erie lines, will conform to the wide gauge, and thus in time, by a judicious action of the Northern Pacific Company, the whole northern portion of the country will come in possession of a superior system of roads having the uniform gauge of 6 ft.

These changes, which are very sure to follow the adoption of the right gauge on the Northern Pacific Road, are not essential in their bearing upon the business of that road, for it is very easy to show that, upon a road of the great extent of the Northern Pacific and its branches, it will not be for the interest of the Company or its true policy to permit its cars and engines to pass beyond its own control on to other roads; neither will it be necessary or expedient, but a great injury, to admit upon its tracks the cars and the engines from other roads.

Under a moderate estimate the Northern Pacific Railroad Company will, in a few years, have under its management, no less than about 2,500 to 3,000 miles of railway, with a rolling stock consisting, probably, of not less than 1,000 locomotives and nearly 20,000 freight and passenger cars. This surely will be a concern large enough and complicated nouugh to be confined to one management or control; and if but one change or transfer of passengers and freight is made in the long distance between the Atlantic and Pacific Oceans, at St. Paul, for instance, it will not be felt, nor can it be measured as an inconvenience of any account.

The centre of population for the entire country east of the Rocky Mountains, having direct and frequent communication with the Northern Pacific Railroad, is now in Eastern Ohio, and is moving steadily in the direction of the southern extremity of Lake Michigan. A very large portion of the travel and traffic over the Northern Pacific Railroad will be to and from the densely peopled region between the Alleghanies and the Mississippi river, and hence St. Paul, and particularly Chicago, must become leading points for the distribution of that traffic, and of breaking of bulk; and in this particular, when Chicago is made the place of junction of the river and lake navigation, by the improvement of the Illinois and Michigan Canal to that extent as to permit river steamers to pass through it, it will become a very great point for concentrating and distributing the trade of the interior west of the Alleghanies. There will, without doubt, be other points of the same character for that portion of the traffic seeking lake navigation, and Milwaukie, and Green Bay, and Mackinaw, on Lake Michigan, and the western extreme of Lake Superior, will be among the principal of those points.

All of the heavy agricultural and mineral and timber products from the vast region tributary to the Northern Pacific Railroad and its branches, which, on their way to an eastern or southern market, will seek the cheaper or more convenient navigation of the lakes, or of the larger rivers intersected by the road, will be brought to those navigations without change of gauge; but if this were not the case, the superiority of the broad gauge, used as it would be for a mean distance of 1,000 miles for the conveyance of those products, would fully justify a single transfer from one gauge to another, and leave a large balance both of time and money in favor of the broad gauge. It is believed that an addition of 8 to 10 miles per hour to the average speed for passengers, and the great saving in wear and tear under the same speed, will be cheaply purchased at the cost of 1 or even 2 transfers.

The Northern Pacific Railroad, while it will be more important and efficient, if rightly built, equipped, and managed, than any other transcontinental line, in securing to our people the trade of the Pacific, which is yet to be, for obvious reasons—viz., the dense population and advanced civilization of Eastern Asia, and low price there of human labor—the most profitable theatre in the future of ocean commerce, is also a part of a line or lines traversing the entire space from ocean to ocean, over which, if it be properly constructed and operated, will pass a very large portion of the travel between Europe and Eastern Asia. For this business, which will be very large, the route by the Suez Canal, and the lines of railway which will ultimately be extended eastward from Europe, or from the Mediterranean, will be competitors; and hence the greater necessity of so building, equipping, and operating the Northern Pacific Railway, that it shall not be excelled in the essential qualities of speed, power, economy, and comfort, by any other similar medium of communication. This is of the utmost importance, in view of its true character, which is so far above and beyond that of a great national work as to be the highway over which will pass many thousands of persons annually, from the most remote portions of the globe.

In conclusion, it may be stated that England gave to France and Belgium the accidental gauge of 4 7-10 ft., which was accepted without proper investigation, just as it was accepted by certain leading railway companies in this country; 5 ft. appears to be the gauge adopted in Switzerland. When Russia commenced her system of railways, she sent the Chevalier Von Gershier, a most able and accomplished engineer, to examine the railways of England and of this country. He did so, giving much time and labor and thought to the investigation; and on his return, recommended the gauge of 6 ft. for the Russian roads, and the road from St. Petersburg to Tzarsko-Selo was built with that gauge. Subsequently, the Russian Government employed an American engineer, and on his recommendation changed the gauge of the roads to 5 ft.

It is now understood that several leading engineers in Europe, dissatisfied with the narrow gauge of 4 7-10 ft. or 5 ft., are seriously considering the question of recommending the gauge of 6 ft., as the best uniform gauge for the entire of Northern Europe and Asia.

FULTON.

THE MONT CENIS TUNNEL.*

From "Engineering."

Allusion was made in the last article to the elevated temperature, and to the vitiation of the air in the tunnel. These two causes excluded the possibility of the use of steam-worked machinery. Had this motor been used it ought to have been produced on the spot, because steam cannot be transmitted to considerable distances, without condensing; and as for the production of steam, fire is wanted, the surrounding temperature would have been insupportable, and would, further, through the absorption of oxygen, have made the air totally unfit for respiration.

Further, work is synonymous with heat produced, and hence the work itself, done by the machinery, would have contributed to render the temperature unbearable, had not the heat developed been counteracted by the motive power itself, which produced the work. For all these reasons it was self-evident that if mechanical means were to be used (and the work could not be accomplished without them), the motive power of the machinery employed was to be produced outside the tunnel, and carried along in the tunnel to the very spot where machinery was to be applied.

This problem had but one solution, which consisted in the application of compressed air as a motive power. This solution seems self-evident at first sight, because the application of compressed air as a motor is not a new idea nor a new invention.

Father Hall, a Hungarian Jesuit, in the middle of the eighteenth century, by means of a waterfall, guided compressed air in a tube to a recipient, from which this compressed air, passing in a second chamber, raised and discharged the water in the mines of Selmecx (Schemnitz).

Further, we remember that Montgolfier invented the hydraulic ram, by which he utilized the *vis viva* gained by water in its fall. But the application of these ideas to the production of mechanical work for the Mont Cenis tunnelling, had to meet with many objections, and great difficulties. The difficulties not only consisted in the invention of compressing machinery capable of compressing the immense quantity of air wanted; they also arose from doubts on the possibility of constructing large hermetically closed recipients, such as would not allow the digression of the air.

Experiments had to be made on this subject, and a recipient was erected at Bardonnèche. It was filled with air compressed to 6 atmospheres, and was left 24 days untouched. Fortunately, only a very small loss was detected as having taken place, which did not even amount to $\frac{1}{5000}$th part of the daily production.

It was objected that the transmission of compressed air to great distances, for the purpose of moving machinery, would hardly be possible, because of the loss of the pressure of the air produced by its friction along the conducting tube. This objection was considered a very serious one, as it was stated by great mathematicians, who made out apparently correct theories on the action of gases through long tubes. Further, several unsuccessful attempts had already been made to transmit compressed air, by Wilkenson and others.

It is true that Girard, and later, D'Aubuisson and Marot, and again, the celebrated Poncelet and Peclet were more successful in there experiments; they were not sufficiently so, however, to decide absolutely the case in favor of the possibility of the undertaking.

By order of the Italian Government, experiments were made on this subject, and more especially on the hydropneumatic compressor proposed by Messrs.

* In the formula on lines 15 and 25 of the third column of page 180 of our last number, "log. should be "hyp. log." The formula on line 30 of the same column also should read $t = a + t_1 = 273 + t$, the signs t and t_1 in this formula standing respectively for the *absolute* temperature of the air and the temperature expressed in the ordinary way, these temperatures being taken in degrees of the Centigrade scale. Also on line 10, from the bottom of the second column of page 180, "65.7 in." should be "65 ft. 7 in."

Sommeiller and Grattoni. The results of these experiments may be summed up in the annexed Table.

From this Table we see that for a length of 7,108 yards, with tubes of $3\frac{15}{16}$ in. diameter, supposing the original velocity per second to be 16 ft. $4\frac{13}{16}$ in., the loss of pressure at the end would only be $39\frac{11}{16}$ in., that is, about $1\frac{1}{3}$ of an atmosphere. Putting the initial velocity only at 13 ft. $1\frac{7}{16}$ in., the loss of pressure would be reduced to $27\frac{5}{8}$ in. or $\frac{9}{10}$ths of an atmosphere, and if we suppose the tube to have 20 per cent. greater diameter, the loss would still be reduced by the half of this latter loss.

LOSS OF PRESSURE IN 1093.6 YARDS IN INCHES OF MERCURY.

Diameter of the tubes			in. $3\frac{15}{16}$	in. $5\frac{7}{8}$	in. $7\frac{1}{8}$	in. $9\frac{13}{16}$	in. $11\frac{13}{16}$	in. $13\frac{3}{4}$
	ft.	in.						
Initial velocity per second.	3	$3\frac{3}{8}$	$\frac{15}{64}$	$\frac{5}{32}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{5}{64}$	$\frac{5}{64}$
	6	$6\frac{11}{16}$	$1\frac{1}{32}$	$\frac{45}{64}$	$\frac{33}{64}$	$\frac{7}{16}$	$\frac{23}{64}$	$\frac{5}{16}$
	9	$10\frac{1}{16}$	$2\frac{7}{16}$	$1\frac{21}{32}$	$1\frac{7}{32}$	$\frac{63}{64}$	$\frac{43}{64}$	$\frac{45}{64}$
	13	$1\frac{7}{16}$	$4\frac{1}{4}$	$2\frac{53}{64}$	$2\frac{1}{8}$	$1\frac{41}{64}$	$1\frac{27}{64}$	$1\frac{7}{32}$
	16	$4\frac{13}{16}$	$6\frac{37}{64}$	$4\frac{13}{32}$	$3\frac{5}{16}$	$2\frac{41}{64}$	$2\frac{13}{64}$	$1\frac{57}{64}$
	19	$8\frac{3}{16}$	$9\frac{11}{64}$	$6\frac{9}{64}$	$4\frac{39}{64}$	$3\frac{45}{64}$	$3\frac{5}{64}$	$2\frac{41}{64}$

The final results of the experiments alluded to above, are shown in the following Table :

Area of the orifice.	Velocity per second.				Gauge at the end of the tube.	Loss of Pressure.	
	In the tube.		When issuing.			Observed.	Deduced from the curve of interpolation.
Square inch.	Feet.	Inches.	Feet.	Inches.	Inches.	Inches.	Inches.
.0281	3	$3\frac{13}{16}$	488	10	$14\frac{7}{8}$	.1525	.1525
.0983	10	$5\frac{13}{16}$	473	$0\frac{7}{8}$	$14\frac{13}{16}$	2 0472	1.7656
.0983	11	$5\frac{7}{16}$	501	$11\frac{5}{8}$	$14\frac{59}{64}$	3 1093	2 125
.0983	11	$9\frac{13}{16}$	526	$10\frac{5}{8}$	15	2 7187	2.25
.0983	13	$5\frac{9}{16}$	600	$4\frac{3}{4}$	$14\frac{11}{16}$	2 3936	2.875
.1264	14	$5\frac{3}{4}$	495	1	$14\frac{7}{8}$	3.2677	3.344
.2776	33	$3\frac{7}{8}$	526	$2\frac{3}{4}$	$14\frac{25}{64}$	15 3906	15 2031
.4844	49	$6\frac{7}{8}$	448	2	$14\frac{3}{4}$	35 5468	35.5468
.7639	60	$6\frac{1}{8}$	347	6	$14\frac{9}{32}$	61.4218	61 4218

The preliminary results observed at Bardonnèche confirmed those obtained by the experiments we have alluded to. In the Table given above we find that for a tube of $7\frac{7}{8}$ in. diameter, the air being compressed at 6 atmospheres, and the velocity being at the commencement $39\frac{3}{8}$ in. per sec., the compressed air would lose for every 1093.6 yards, a part measured by a column of mercury of $\frac{1}{8}$th of an inch in height. Comparing this loss with the atmosphere, the loss would be represented by $\frac{6}{760}$, or $\frac{1}{127}$th of an atmosphere for 1.-24276 miles. Now when these tests were made at Bardonnèche the length of the tube conveying the compressed air was precisely this length. It had a diameter of $7\frac{7}{8}$ in.; the velocity of the air at the origin was 3 ft. and $3\frac{3}{8}$ths in. per sec., and hence the volume of compressed air flowing out at the opening was 1.109 cubic ft. Nine perforating machines working together consumed 9531 cubic ft. every sec., and the loss of pressure at the extremity of the tube was found a little inferior to $\frac{1}{127}$th part of an atmosphere ; and hence the result deduced from the Tables was confirmed by those practically obtained at Bardonnèche.

It may be interesting to give here a few theoretical observations on the movement of gas in tubes, nor will it be out of place, the subject being closely connected with the motive power which was used to carry out the perforation of the tunnel under the Alps. Besides, compressed air as a motive power, will no doubt receive very wide and important application in future, and hence mechanical and civil engineers cannot sufficiently study the questions which are connected with the important problem to the solution of which the possibility of the completion of the tunnel is owing.

Compressed air, and, indeed, almost all gases moving along a tube, encounters a certain amount of resistance owing to friction. If we represent by L the length of the tube, and D its diameter, the loss of pressure occasioned by the friction alluded to, is represented by

$$H-h=K\frac{L\,v^2}{D\,2\,g},$$

where H and h are the pressures at the beginning and the end of the tube, measured in columns of the same gas, at the density it has at the section at which the velocity, v, is taken, and where K is a numerical coefficient (the coefficient of friction=0.0236), and g is the accelerating force of gravity.

Let H_1, H^1, and h be respectively the pressures in the reservoir at the starting, near the orifice of outflow, and externally, measured in columns of gas of the density of the gas in the reservoir, D and d being the diameter of the tube, and of the orifice by which the gas flows out; further, $\phi\ \psi$, the coefficients of contraction at the entrance into the tube, and at the orifice of escapement, and K that of friction, as said above; v the initial velocity in the tube, $a+t^1$ the absolute external temperature, and $a+t$ the absolute temperature of the reservoir.

The general equation of the motion of the gas in a rectilinear tube of uniform section will be

$$H-h=\frac{v^2}{2g}\left\{\left(\frac{1}{\phi^2}\quad 1\right)\times K\frac{L}{D}+\frac{D_4\,H\,(a+t^1)}{\psi^2 a^4\,H^1\,(a+t)}\right\}$$

To obtain the pressures measured in columns of mercury, if P_1 P^1 and p are the heights of mercury equivalent to H H^1 and h of gas; and δ being the tubular density of the gas, we shall have

$$H.\delta\times 1{,}3\frac{P}{0{,}760}\frac{a}{a+t}=13596\ P,$$

whence

$$H=7990\frac{a+t}{a\,\delta},$$

and

$$H-h=H\left(1-\frac{h}{H}\right)=7990\frac{a+t}{a\,\delta}\left(1-\frac{p}{P}\right)$$

and the equation of the movement of gas shall become

$$P-p=\frac{a\,\delta\,P}{7990(a+t)}\left\{\left(\frac{1}{\phi^2}-1\right)+k\frac{L}{D}+\frac{D^4\,P\,(a+t^1)}{\psi^2 a^4 P^1\,(a+t)}\right\}\frac{v^2}{2\,g}.$$

If we wish to have the volume of the outflowing gas at every second, respectively at the temperatures and pressures P and t^1, and p and t^1, they will be given by

$$Q=\pi\frac{D^2}{4}v \text{ and } Q^1=\pi\frac{D^2}{4}\frac{P\,(a+t^1)}{p\,(a+t}v.$$

The exactness of these formulæ at low and middling pressures, has been sufficiently proved by the results of the experiments made.

To illustrate them, let us apply them to air moving in tubes of 0.01028 metre diameter, of the length between 0.07 and 18 metres, allowing the air to flow freely into the atmosphere under a constant pressure of one atmosphere, we shall have $\delta=1$ and $\psi=1$ and P^1 very approximately equal to P; further assuming $\frac{1}{\phi^2}-1=1.475$, *i. e.*, $\phi=0.636$ and $t=t^1=20°$ $\frac{1}{a}=\frac{1}{250}$, instead of $\frac{1}{273}$ in order not to neglect the aqueous vapors existing in air, we shall have

$$Q^1=410{,}305\,\pi\frac{D^2}{4}\frac{P}{p}\sqrt{\frac{1-\frac{p}{P}}{2.475+0{\cdot}0236\frac{L}{D}}},$$

in which we shall make $\frac{p}{P}=2$ and $D=0.01082$. The following table gives the results calculated with this formula by M. Cavallero:

Length of the tube (L).	Values of Q^1 (volume of the out-flowing gas) by experiment.	Values of Q^1 by calculus.	Differences.
Metres.	Metre cube.	Metre cube.	Metre cube.
18	0.00724	0.00719	0 00005
9	0.00989	0.00989	0.00000
4.50	0 01380	0 01331	0.00049
2.25	0 01721	0.01727	0.00006
1.125	0.02032	0.02127	0 00095
0.562	0 02480	0 02471	0.00009
0.281	0.02760	0.02720	0 00040
0.14	0.02869	0 02876	0.00007
0.07	0 02869	0 02965	0.00096

From the experiments made on this

subject, the following empirical has been deduced:

$$v = \frac{2225\, p \sqrt{D^5 (F-0\ 76)}}{\pi\frac{D^2}{4}\, P \qquad L + 42\frac{D^5}{d^4}}$$

which serves to the determination of the velocity, v, at the origin of the tube.

The experiments made on the hydro-pneumatic compressor of Messrs. Sommeiller and Grattoni (to which I alluded in my last letter), have proved that the formula given above does not hold for high pressures.

The same fact can be demonstrated theoretically. The loss of pressure owing to friction is expressed by

$$\frac{P-p}{P} = \frac{a\,\delta}{7990(a+t)} K \frac{L}{D}\frac{v^2}{2g},$$

whence

$$P-p = \frac{a\,\delta\, K}{7990(a+t)} P \frac{L}{D}\frac{v^2}{2g}.$$

If we now consider separately two portions of tube of the respective lengths of L_1 and L_2; and if P and P^1 and P^1 and p the initial and final pressures of the two portions, v and v^1, the velocities at the end of the lengths, L_1 and L_2, we shall have, when applying the last formula,

$$P-P^1 = \frac{a\,\delta\, K}{7990(a+t)} P \frac{L^1}{D}\frac{v^2}{2g},$$

and

$$P^1-p = \frac{a\,\delta\, K}{7990(a+t)} P^1 \frac{L^2}{D}\frac{v^2}{2g}.$$

$$P-p = \frac{\frac{a\,\delta\, K}{7990(a+t)}}{2\,g\,D}(P\, L_1\, v^2 + P^1\, I_2\, V^{1\,2}).$$

The temperature of the tube being constant,

$$P\, v = P^2\, v^1,$$

hence

$$P-p = \frac{\frac{a\,\delta\, K}{7990\,(a+t)}}{2\,g\,D}(L^1\, v + L_2\, v^1).$$

Now, as

$$v^1 = v + (v^1 - v),$$

we have

$$P-p = \frac{a\,\delta\, K}{7990\,(a+t)} P \frac{L}{D}\left\{1 + \frac{L_2\,(v^1-v)}{L\, v}\right\}\frac{v^2}{2\,g},$$

which is different to the one found above for low pressures, and the difference is directly proportional to the difference between P and P^1.

Before leaving this subject, I wish to lay before your technical readers some very simple formulæ presented to the Royal Lombard Institute by M. Cagnoni, which are probably unknown to them.

M. Cagnoni started from D'Aubuisson's simple formula:

$$A - a = 0.0238\, a \frac{L\, d^4}{D^5},$$

where a and A are the manometrical heights of mercury at the end and at the beginning of the tube; d the diameter of the opening of outflow, D the diameter, and L the length of the tube, putting D=006m., and L=400m. (which were the conditions of the experiments made on Messrs. Sommeiller and Grattoni's hydro-pneumatic compressor) D'Aubuisson's formula becomes

$$a = A\frac{1}{1+123130000\, d^4},$$

when the results given by this equation were calculated, they were found two or three times higher than those the practical experiments gave.

M. Cagnoni then made the hypothesis that an elastic fluid, flowing out from a long tube of constant diameter, and under a permanent pressure, with velocity and density different in the various sections, would behave approximately as a liquid, which would have a uniform velocity equal to the medium of the velocity of the fluid corresponding to the extremities of the tube, and a uniform density also equal to the medium of the densities corresponding to the same extremities; starting from this hypothesis, M. Cagnoni deduced:

$$A - a = 0.000000103\, \delta \frac{L}{D} u^2$$

in which A and a are the pressures in metres of a column of mercury at the beginning and at the end of the tube; δ and u the media density and the velocity as explained above.

Applying this formula to the determination of the coefficient

$$0.000000103\, \delta.$$

M. Cagnoni found the following numbers, substituting for A, a and u, the values taken from D'Aubuisson's experiments,

$$0.000000103\, \delta = 0.0000001318$$
0.0000001311
0.0000001317
0.0000001325
0.0000001352

medium value 0.0000001326

This would show that the formula under the above hypothesis is applicable to low pressures.

M. Cagnoni, however, comparing the results given by his formula with those obtained in the experiments made on

Messrs. Sommeiller and Grattoni's machine, proved that it is also very approximatively applicable to high pressures.

The following table clearly shows it:

Velocity at the origin of the tube.	Difference of pressure (A – a)	
	Obtained in practice.	Deduced from the formula.
1.012	0 0039	0.0046
3.797	0 0457	0.0459
3.604	0.0577	0.0571
4.106	0.0738	0.0758
4 415	0.0853	0 0877
10.157	0.3660	0.4641
15.100	0.9030	1.0260
18 460	1.5560	1.5330

The formula itself is transferred

$$A-a=0.0818\,\frac{b+a}{(b+a_1)_2}\,\frac{L\,d^4}{D^5},$$

introducing in it, instead of the medium velocity, a function of the diameters D and *d* of the tube, and of the opening of outflow and in which $b=0.76$ $a_1=\frac{1}{3}(A+a)$, L=length of the tube, and A and a keeping their former meaning.

Introducing further the quantity Q of fluent air reduced to the volume of ordinary atmospheric density, M. Cagnoni deduced

$$(b+a)^2=(b+a)^2+M\frac{L}{D^5}Q^2,$$

in which M is a numerical coefficient which may be taken=0.0000002567.

THE ART OF SPOILING PUBLIC BUILDINGS.

From "The Building News."

To those who have been behind the scenes there is something amusing in the reasons popularly assigned for our great architectural failures. One writer will tell us that the English nation has no artistic powers. We once, it is true, produced such trifles as the choir of Lincoln, the octagon of Ely, and the spire of Salisbury; we covered the land with abbeys and parish churches which are not quite unworthy of notice, and we produced a quantity of domestic architecture which, if it is not showy, at any rate cannot be called coarse or vulgar. No matter; we *are* inartistic, and we ought to be proud of it. So our journalists frequently assert, not of course in so many words, but in that form of modest confession which cloaks the most outrageous type of vanity, the vanity which feeds even on weakness and incapacity. "Nature has not endowed us," we are told, "with the artistic talent of the French, the plodding industry of the Germans," etc., etc.; and there is an underhand implication throughout that all such qualities as these are very poor things, only fit to be despised as unworthy of our transcendent greatness. Another writer, with a little more discernment than the last, looks at our architectural failures with regret. He sees that we did not always fail, and he is sorely puzzled to find why we should do so now; and at last, not being able to discover any sufficient reasons, he ends by setting it all down to chance. We have had a run of bad luck, he fancies, in our public works; some day the tide may turn, and we shall do better. It is a matter of accident; we have been unfortunate, and there is no more to be said about it. Now for our own part we entirely dissent from both these theories. Our public buildings, as we believe, are spoilt neither by accident nor by incapacity, at least on the part of the nation at large. The spoiling of them is an ingenious and complicated process, which may properly be called an art, and of all the arts it is perhaps that which in modern England flourishes the most.

The best way of explaining the system will be by example. Suppose, then, that it is a new town-hall or vestry-hall, or church or chapel, that is wanted, and trace the common methods of proceeding. These methods, indeed, are not quite universal, and so our public architecture is not universally bad. In church building, particularly, the influence of art education amongst the clergy helps to modify them; and whatever our churches may be as regards convenience, in point of art they are often above the average. But we will take an average case, where the management is in the hands of an ordinary committee. If none of the members of this committee know anything about the design of buildings, the prospect is bad enough; but shou there happen to be a "practical man" amongst them the case is ten times worse. For the truly practical man we have the highest respect. If he were only a practical mason or carpenter we would go to him for masonry or carpentry facts within his own knowledge before all the theorists in the world. But the most thoroughly practical man is only an authority in questions to which his practice has extended; and the practice of masonry or carpentry is but a small portion of architectural practice as a whole. The sort of "practical man," however, who generally gets on a committee does not deserve even this amount of respect. Nine times out of ten he is an impostor, empty, plausible, and loud. He has, perhaps, got a few technical terms by heart, or he may have spent a year or two of his youth in a builder's office, or possibly he once drew a house plan which, with sundry indispensable modifications, was ultimately carried into execution. For these or some similar reasons he is held in great veneration by his colleagues; his opinion, which he is never backward in giving, is invested with mysterious weight, and, tacitly promoted to the leadership, he becomes the one-eyed king of the blind. The committee, we will suppose, have obtained a site; their next step is to procure designs. Each member has an architect whom he wishes to recommend, and, as it is impossible to come to a unanimous choice, it is decided to invite a public competition. The practical man draws up the conditions, which are chiefly remarkable for demanding more accommodation than can be expected for the money. Plans, of course, are to be sent in under mottoes, and the author's names are supposed to be totally unknown. It is very remarkable, under these circumstances, that each architect's design should exercise a special attraction on his own private friends; that Mr. A., the chairman, for instance, should think no drawings comparable to those which ultimately prove to have been the work of his own son-in-law, and that Messrs. B., C., D., etc., should each and all show inexplicable affinities of a corresponding kind. There must surely be some occult influence conveyed into the paper from the fingers of the draughtsman, which can only operate on those who are in sympathy with him—a kind of "psychic force," in fact, like that now being investigated by Mr. Crookes. But though everybody on the committee may have his own preferences, everybody, it is plain, cannot have his own way. They must agree on some one design which can command a majority; and so they proceed to discuss what have been sent in. Design No. 1 is very plain; its architect adhered to the conditions and kept within the sum allowed—so he is dismissed at once. No 2 is admitted to be "pretty;" but the practical man asks what need there is for all this waste of money at the sides and back; they only want a "front," and in search of a front they go on to No. 3. This is allowed by all, save a few fastidious members, to be the gem of the collection. It has a magnificent portico, with six Corinthian columns, an entablature with carved acanthus-leaf modillions, and a pediment with a small bull's-eye window in its centre. But this is not all. Contrast, as every one knows, is the soul of art; and what a contrast is here! Behind the Corinthian columns comes a 14-in. brick wall; behind the entablature, a cast-iron eaves gutter; and behind the pediment a hipped slate roof. Such a design could not fail of being adopted by acclamation; but alas! on turning to the plan, it is found too small. Carried away by the inspiration of genius, its author neglected the practical in pursuit of the ideal; he has enraptured the tastes of the committee and they give him a premium; but he has overlooked their requirements, and they cannot carry out his conception. With lamentation and regret they go forward, but the other drawings have almost lost their charm. They come at length on a plan which even they cannot help seeing is a good one; but then the elevation is not "pretty" at all. It is Gothic, and they might bring themselves to endure Gothic if there was plenty of tracery, and gablets, and pinnacles, and crockets; Henry the VII.'s chapel, they think, is very pretty, so is Bethesda Chapel, in the High street; but such Gothic as this they never saw in any chapel of their acquaintance. They accordingly vote it "heavy," and pass on—for heaviness, with committees, is the most unpardonable of sins. At length, puzzled and confused, they have gone through the whole collection. They would like the plan of No. 12, the front of

No. 3, and the interior, say, of No. 20. But to each of these designs, as a whole, there are strong objections; and they end, perhaps, by fixing on a set of drawings which nobody likes, simply because nobody has been able to point out any insuperable objection to them. Their author is accordingly appointed architect, and their committee pride themselves on having acted fairly and having resisted temptation. The next thing they do is to try and import the charms which have attracted them in other drawings into those which they have selected. The architect sees difficulties, and foresees a jumble. He argues, protests, and predicts disappointment. The practical man makes light of his objections, insists that the four designs can easily be amalgamated, and prepares, it may be, some marvellous sketches to show the way. If the architect is weak, the committee overpower him; he submits, perpetrates a jumble, and regrets it forever after. The practical man, having gained his point, rises higher than ever in general estimation, and is appointed supervisor and director of the works. As the working drawings proceed, he looks them through, thins the walls, ruins the details, and takes care that the sides and back of the building shall be sufficiently shabby. All this he does, not so much for the sake of saving money as for the sake of asserting a principle: the grand principle of heaping all the ornament on the front wall. He does not even grudge expense when a reasonable amout of ugliness is to be gained by it, and though he would strike out mouldings as a wasteful extravagance, he revels in lead flats, gutters, and parapets. The next thing is the receiving tenders for the works, which are all, of course, too high. The committee asked for too much in the first place; they rejected, in the second place, the few designs that were within their estimate; and so it is inevitable, as a result, that the cost should outrun their funds. Then comes the cutting down. The design, already half-starved, is now reduced to the extreme of emaciation. Every item on which a saving is possible is reduced; if there was a tower, the tower is omitted; if there was a portico, the portico is flattened into a row of pilasters, the walls become a little thinner yet, the roofs a little weaker, the whole construction a little more trumpery and poverty-stricken. The works go on; the practical man still broods, like a nightmare, over all; and the building turns out at last about as well as if he himself had designed it. Such is the history of many and many a structure, at whose incomprehensible wretchedness all observers (save English ones) stand amazed. Well they may be, for the production of such work would seem impossible if we had not long learned how to do it. It is no easy matter to turn out such public buildings as ours. It could not be done by tossing up for the design to be accepted; it could not be done by blindfolding a committee-man and adopting the first plans he laid hold of; it can only be effected by strenuous and unceasing effort towards the attainment of the lowest possible pitch of degradation.

Our example has been taken from the minor class of public works—from those which are rather local than national; but we manage the latter on just the same grand principles as the former. In great things as well as small, we follow one unalterable rule—that of setting everybody to direct what he least understands, and to do what he most earnestly protests against. If we have, by strange accident, a Minister of Public Works who is equal to his duties, we do not lose a moment in getting rid of him. London would not be London long, with such a man to direct her; make him an ambassador—nay, make him an admiral—rather than let him stay here. Have we an eminent Gothic architect appointed to design a most important building? The risk is imminent of his doing something creditable; our measures must be proportionately violent to hinder him. Compel him to work in a style he hates; even he may then keep our national reputation down to its traditional level. Such a feat as this, indeed, is not given to every man to do. A Prime Minister accomplished it once; but it is somewhat beyond the strength of the poor R.A. who has tried it lately. We venture to hope that the Law Courts may turn out somewhat differently from the Foreign Office, and that we may at last see an architect who, with all the plausible stupidity in England opposing him, will set our precedents at nought, and refuse to have any hand in spoiling work on which he is engaged.

REMARKABLE EXPERIMENTS ON STEAM BOILERS.

A series of very remarkable experiments has recently been commenced by the United Railroad Companies of New Jersey under the immediate direction and superintendence of Mr. Francis B. Stevens of Hoboken.

We are indebted to Professor Thurston of the "Stevens Institute of Technology," for the following account of the work done on the 22d and 23d November.

For a considerable time past Mr. Stevens has been collecting the steam boilers as they were removed, "worn out," from the steamboats of the above-named corporation, and subjecting them to a systematic course of experiment with the object of obtaining some reliable information upon the subject of steam boiler explosions.

Each boiler was subjected several times to hydrostatic pressure until ruptured, the position, character, *et cœtera*, of the break being carefully observed and the boiler then repaired preparatory to another experiment.

This series of experiments afforded strong evidence that the stayed surfaces, which are usually the strongest portions of a new boiler, become finally the weakest in many cases.

In most of the instances referred to above, the stays and braces were the parts which gave way.

After this course of experiment was completed, Mr. Stevens, having been voted $10,000 by the United R. R. Companies for the purpose of prosecuting this work, transported the boilers to Sandy Hook and set them up—with the consent of the Secretary of War and of the President—upon the United States reservation, there to be exploded by steam pressure.

Mr. S. also built several boilers for the latter set of experiments, and set them with the others in an inclosure near the beach and at a considerable distance from any habitation.

The first experiments at Sandy Hook were made November 22, in the presence of a large party of invited guests, including many of our best-known civilian and naval engineers, railroad officials, Government inspectors, and other persons specially interested in the subject.

"*No.* 2" was the first boiler attacked. This boiler was built by Fletcher Harrison & Co., in 1858, and had been in service 13 years. It is an ordinary "return flue" boiler, 6 ft. 6 in. diameter of shell, and 28 ft. long. It was tested in September by hydrostatic pressure, giving way, by the breaking of a stay-bolt, at 66 lbs. After being repaired, it bore 82 lbs. at Sandy Hook, November 4th, without injury, and November 15th was again tested to 60 lbs. pressure.

Steam having been raised in this boiler, a heavy wood fire was built up in its furnaces, the doors were closed and the company moved off to the gauges, which were placed a considerable distance from the boiler enclosure. The gauges were well made and had been carefully tested and proven correct.

Steam rose steadily from a pressure of 60 lbs. to 90 in 18 min. At 92 lbs. leaks became plainly visible, and at 93 they had become so numerous and so large as to let off the steam as fast as generated, and after standing a short time at that point, the pressure gradually decreased, and Mr. S.'s workmen putting out the fires, the experiment came to an end.

"No. 6" was next tried. This was a new construction made as nearly as possible like the back end of the exploded boiler of the Westfield, merely a "water leg," with stays distributed as in the boiler of that unfortunate steamer. It is made of Abbott's best flange fire-box iron, 5-16 in. thick, and the stay-bolts were without nuts and of $1\frac{1}{8}$ in. iron. This "leg" was set in brick-work and fires built on both sides of it, the water-line being entirely above the fire surface. It had been previously tested without injury to 138 lbs. per sq. in., cold water pressure, and with 102 lbs. steam pressure.

During this experiment, steam rose from 4 to 20 lbs. in 10 min., from 20 to 40 in 6 min., from 40 to 80 in 7 min., from 80 to 160 in 9 min., and in 27 min. from the moment when the gauge showed 4 lbs., and at a pressure of 165 lbs., or a trifle over, a violent explosion occurred, tearing the "leg" into two parts, which were thrown far apart, and scattering the brick-work over a wide area of ground, portions of the latter falling among the spectators at the gauges.

The screw stay-bolts had drawn out and

the sheets had then been torn away from the rivets at their edges. Both halves were deeply dished, and around the points at which the stay-bolts had taken hold, the surface coating of oxide had been off along the lines of compression, where the metal had *wrinkled*, and the delicate lines thus marked presented a curiously interesting appearance, and bore some resemblance to the magnetic spectra described by physicists.

Next day, November 23d, a third boiler was experimented upon. This boiler, "No. 3," was built in 1845 by T. F. Secor, and had been in use 25 years. The U. S. Inspector's certificate allowed, at the time of its removal, 30 lbs. pressure to be carried. It was a "return tubular" boiler, 12 ft. wide, and 15 ft. 5 in. long. The furnace extended the whole width of the boiler, its flat crown-sheet being stayed to the shell by "crow-foot" braces.

In September, under hydrostatic pressure on the wharf, a brace broke in the crown-sheet at 42 lbs., and at 60 lbs. pressure 12 had given way. After being repaired, it bore 59 lbs. per sq. in. in its position at Sandy Hook without fracture, and was after subjected to a steam pressure of 45 lbs.

Steam being raised on this boiler, on the 23d inst., at 50 lbs. pressure, a loud report indicated the breaking of braces, and at $53\frac{1}{2}$ lbs., the water standing at a height of 15 in. above the tubes, a tremendous explosion tore the boiler completely to pieces, throwing some of its parts several hundred feet.

The result of the first experiment had a tendency to confirm many of the party present, in the singularly general belief that explosions never occur except when the boiler has an insufficient supply of water, but the second experiment was a severe blow, and the last completely dissipated any remaining prejudice of that nature, and it is proven, beyond the possibility of a doubt, that a most destructive explosion may be possible with plenty of water and at a moderate pressure. Probably very few of our expert and scientific engineers required to be taught the fact in this decisive manner, but the belief referred to is so general among engine drivers and others who are most nearly concerned in the matter, that we cannot doubt that we are indebted to Mr. Francis B. Stevens, for the preservation in the future of many lives and an incalculable amount of property.

These experiments will be continued until the nine boilers now referred to are all destroyed; and, at the close of the work, a carefully prepared and exhaustive account will be made public.

It is certainly the duty of every steamboat and railroad company to consult their own interests as well as those of the public, and to assist in this work either by placing in the hands of Mr. Stevens large additions to the fund established by the united R. R. companies, or by conducting independent experiments, and it is to be hoped that the General Government will also lend pecuniary assistance in this truly humane enterprise.

PNEUMATIC DESPATCH TUBES—THE CIRCUIT SYSTEM.*

From "The Engineer."

The author commenced by remarking that, soon after the introduction of the electric telegraph, it was found necessary, in large towns, to establish branch telegraph stations, at which messages could be collected for, and to which messages could be sent from, the central station. Both telegraph wires and messengers were tried for the purpose of keeping up communication between the central and branch stations; but neither of these means was found perfectly satisfactory, as the messengers proved too slow, and re-telegraphing the messages added another chance to their being mutilated in transmission. Under these circumstances, the Electrical and International Telegraph Co. connected their central station in Telegraph street, and their nearest branch stations in the city, by means of pneumatic tubes, through which carriers, containing messages, were forced in one direction by compressed air, and in the other by the air of the atmosphere flowing through the tubes into an exhausted re-

* A paper read before the Institution of Civil Engineers, by Carl Siemens, C. E.

ceiver. This system of tubes, which was designed and carried out by Mr. Latimer Clark, M. Inst. C. E., and Mr. Varley, M. Inst. C. E., was still in existence, and had indeed been considerably extended since the telegraphs had passed into the hands of the post-office authorities. It was worked by means of air-pumps, actuated by steam engines placed in the basement of the central station. This system had comparatively a very limited power of despatching messages, except for short lengths, as it was necessary to wait till a carrier had completed the whole of its journey in one direction before another could be sent in the other direction, and it did not admit of intermediate stations being inserted, but every two stations must be connected by means of a separate tube.

In April, 1863, the Prussian Government applied to Messrs. Siemens and Halske, of Berlin, to propose a system of pneumatic tubes for that city. After making numerous experiments, that firm proposed laying tubes, arranged in a circuit, to be traversed by a continuous current of air always kept flowing in the same direction. The peculiarities of this system, namely, the continuous current of air and the power of putting carriers into the tubes at any point, gave it great superiority over previous systems in the amount of work it was capable of doing. The Central Telegraph Station and the Exchange at Berlin were connected together, on Messrs. Siemens and Halske's system, in 1865, by means of two parallel lines of drawn wrought-iron tubing, 2 1-2 in. internal diameter, one tube being used exclusively for the passage of carriers in one direction, and the other for carriers going in the opposite direction. The continuous current of air was produced by means of a steam engine, working a double-acting air-pump, in the basement of the Telegraph Station. After the first line had been in use in Berlin for a year and a-half, and had proved perfectly satisfactory, the Prussian Government ordered an extension from the Telegraph Station to the Potsdamer Thor, with an intermediate station at the Brandenburger Thor, and expressed the intention of providing the whole of Berlin at a future time with a network of pneumatic tubes. The total length of the pneumatic lines laid in Berlin was 32,000 ft., including the first experimental line of 5,670 ft. On account of the great length of the second circuit of tubes they were made 3 in. in diameter inside, and this dimension would be adhered to in future extensions.

There was also a circular pneumatic system in Paris, but the continuous current of air was not used. Messrs. Siemens and Halske recommended their plan to the French Government before the Berlin line was constructed; but the French Government preferred a modified arrangement of their own. Each station on the French line was provided with large air-tight vessels, which were in communication with the water mains of the town. By admitting water under a considerable pressure the air in the vessels could be compressed to about two-thirds of its volume, and by means of the air so compressed the carrier, or train of carriers, was driven to the next station, from whence it was again driven to a further station, by the air which had been compressed in another set of vessels, and so on, from one station to another, at stated times, round the circuit. The author observed that the consumption of water by this system must be enormous, because, as the air was compressed to two-thirds of its ordinary volume, for every volume of air used the expenditure of a volume and a-half of water was required. The French line was circular, in so far as it started from the Central Telegraph Station, and passed through four stations, namely, at the Madeleine, the Grand Hotel, the Bourse, and Post-office, and returned to the Central Telegraph Station; so that the carriers were always sent through the tubes in the same direction. The working powers of this system were of course very limited.

In London there was another pneumatic line which should be mentioned, although not designed for the conveyance of telegrams or single letters, but of large parcels; namely, the large cast-iron tube, of a D section, running from Euston Station, *via* Holborn, to the General Post-office.*

Five or six years ago, Messrs. Siemens Brothers tried to induce the Post-office authorities to adopt their system of pneumatic tubes for the conveyance of

* Fuller information with respect to this line will be found in a paper read before the British Association, in 1870, by Robert Sabine, Assoc. Inst. C. E. *Vide* "Engineering," Sept. 23, 1870.

letters in London ; but it was only in December, 1869, when the telegraph lines were being taken over by the Government, that they received an order to lay an experimental circuit between the Central Telegraph Station and the General Post-office in St. Martin's-le-Grand. This line was completed and opened for traffic in February, 1870, and, after half a year's work, the great advantages of the system having shown themselves, a further length to Fleet street, and subsequently to the West Strand office at Charing Cross, was decided upon. The different stations were connected by two lines of wrought-iron tubing, having an internal diameter of 3 in.; both lines were laid in the same trench, at a depth of about 12 in. below the pavement, and parallel to one another. The tubes forming the circuit were of an average length of 18 ft. 8 in. For turning round street corners, and for rising and falling in the different buildings, pieces bent to a radius of 12 ft. were used. The ends of every two consecutive tubes were brought close together, and joined by means of a cast-iron "double collar," similar to those used for joining cast-iron water pipes, but having in the centre of its length an annular projection 2 in. wide, which was bored out just to fit over the ends of the tubes to make them butt true. A common lead and yarn joint was made at each end of the collar. Water-traps, communicating by means of slots with the bottom of the tubes, were placed at depressions on the line, to enable water, which might have got into the tubes through condensation or otherwise, as well as dust, or foreign matter, to be drawn off, without its being necessary to take up any of the tubes. A current of air was constantly circulating through the tubes, by means of a steam engine and double-acting air pump, supplied by Messrs. Eastons, Amos, and Anderson, placed in the basement of the Central Telegraph Station. Each station on the circuit had two sending and receiving instruments, one on the top and another on the down line of tubes. The instruments consisted of two short tubes, fixed side by side in a rocking frame, each of which could be brought into line with the circuit of tubes, at the pleasure of the attendant. Each end of the rocking frame was faced, and worked against the faced side of a boss, into the centre of which was fixed a piece of wrought-iron tube, forming part of the circuit. Three annular grooves were turned in the faced side of the boss round the tube forming the end of the circuit. The use of these grooves was to prevent the escape of air between the ends of the rocking frame and the bosses at either side of the apparatus. One of the tubes in the rocking frame, that called the sending or "through" tube, was simply a hollow cylinder, of the same internal diameter as the tubes forming the circuit. When this tube was in line with the main tubes a carrier could pass through the instrument without being stopped, and this tube was used when it was desired to put carriers into the circuit. The other, or receiving tube, had a perforated diaphragm at its "down stream" end, so as to arrest the carriers when it was placed in line with the main tubes of the circuit. This tube was D-shaped in section, with a flat cover, which could be taken off if required; as, for instance, to remove carriers, should two arrive at once, and so prevent the rocking frame being moved. The flat cover of the receiving tube was furnished with a pane of glass, to enable the attendant to see when a carrier had arrived. To prevent the continuous flow of air in the whole system of tubes from being impeded, should the receiving tube be left in circuit after it had caught a carrier, there was a by pass, which communicated with the tubes of the circuit on both sides of the instrument. A sliding rod, held on suitable supports, was supplied for pushing the carriers out of the receiving tube when intercepted and brought out of the circuit. The manipulation for sending and receiving carriers was exceedingly simple, and a treadle was provided to enable the attendant to move the rocking frame with his foot. The carriers for the reception of telegrams, letters, etc., consisted of small cylinders made of gutta-percha, papier maché, or tin, covered with felt, drugget, or leather. It was found in practice that the carriers need not fit the tubes at all accurately. Mr. Cullie, M. Inst. C. E., chief engineer of the post-office telegraphs, had adopted the block system, such as was used on railways, for working the tubes, and he employed instruments introduced by Mr. Tyer, Assoc. Inst. C. E., for making the signals. The use of the block system prevented the tubes being able to develop their full working powers, which would be obtained by sending carriers one after another at half-minute or shorter intervals—a mode of working that could be easily carried out with a constant current of air, as was the case when the circular system was worked independently of other systems, which was not yet the practice in the metropolis. The total length of line now working in London, from Telegraph street to the West Strand Office and back, was 6,890 yards, as follows: From the instrument room on the third floor of the Central Telegraph Station to the General Post-office, 852 yards; from the General Post-office to the Fleet street street office, 1,206 yards; and from the Fleet street office to the West Strand office, near Charing Cross, 1,387 yards.

The following results as to speed were obtained during experiments made with the two sections first opened. The mean pressure during those experiments was 7 lbs. per sq. in. at one end of the circuit, and the vacuum at the other end of the circuit was 11 in. of mercury; under these conditions, the circuit being worked with both pressure and vacuum, the times were:

	Yds.	m.	s.
Telegraph street to General Post-office..	852 ..	1	54
General Post-office to Temple Bar......	1,206 ..	2	28
Temple Bar to General Post-office....	1,206 ..	2	10
General Post-office to Telegraph street.	852 ..	1	13
	4,116	7	45

These experiments proved that the speed of the carrier was much greater as it approached the vacuum end of the tube than it was at the other end.

The necessity of having a steam engine with air-pumps and reservoirs was a great hindrance to the general introduction of pneumatic tubes; but this inconvenience had been successfully removed by the construction of an exhausting apparatus, working by the direct action of steam upon a current of air. In this exhausting apparatus the steam from a boiler was made to issue, in the form of a hollow cylinder, from an annular nozzle placed in the centre of the apparatus, the opening having a width of about one millimetre all round. The steam issuing in this form had the greatest possible surface, both inside and out, for contact with the air in the apparatus, which air was in connection with, and was drawn from, the pneumatic tubes. With one of these exhausters a vacuum equal to a column of 23 in. of mercury was obtained, with a less expenditure of steam than would be required to work a steam engine and pump to effect the same object. The principal recommendation of the steam exhauster, besides its extreme simplicity and the small space it occupied, was its cheapness of construction, as the cost only amounted to about one-twentieth part of an engine and pumps.

Where so large a traffic was not expected as in London, the tubes, instead of being laid side by side in the same trench, could, at a trifling additional cost, be laid in a large circuit, and so be made to include many more intermediate stations, each station in that case having only one sending and receiving instrument.

Experiments made at Berlin prove that, in very long lines of tubes of small diameter, a sufficient velocity of the column of air could be obtained with the pressure of the two ends differing within quite practical limits. If the carrier was made so as to move with very little friction, its speed would be nearly equal to that of the air by itself. The momentum of the carrier and that of the column of air might be entirely disregarded, as both were infinitely small when compared with the prevailing friction of the air in the tube. As under equal conditions of pressure at the two ends the speed in the tube increased as the square root of the diameter, and decreased as the square root of the length of the tube, the length of a pneumatic system might be extended with similar results as to speed, in the same proportion as the diameter of the tubes could be increased; that is, the same speed as was obtained through a tube of a certain diameter and length, might be obtained through another of double the length and double the diameter, the difference of the pressures at the two ends of the tubes remaining identical.

Up to the present time, as far as the public was concerned, the pneumatic tubes in London, Berlin, and Paris, had only been used for the conveyance of telegraphic messages; but the British Post-office authorities had already considered the question, whether it would not be advantageous to have the letter-post service in London executed by means of pneumatic tubes. With such a system of distribution an accumulation of letters at principal offices would be entirely avoided.

CANADIAN PETROLEUM.

From "Engineering."

During the last 20 years rapid advances have been made in the development of mineral oils, and their growing importance for illuminating and various other purposes gives them a high commercial value. The natural oils which flow from the earth were familiar to the ancient inhabitants of the world, both civilized and barbarous. Thus Herodotus, who wrote 440 years B.C., mentions a place called Arderrica, 35 miles from Susa, where there were wells yielding bitumen, salt and oil. The products of these wells were drawn off in utensils formed of wineskins cut in halves, and were allowed to settle in tanks. Here the bitumen and salt settled and hardened, the oil being drawn off into casks. This oil was known to the Persians as "Rhadinace;" it was black and had an unpleasant odor. The Persians, Burmese, and other nations still continue to employ these substances in their crude state to give light, and for medicinal purposes. In 1694 we have it recorded that Messrs Eeely, Hancock, and Portlock obtained a patent for making "pitch, tar, and oyle out of a kind of stone." In 1761 oils were distilled from black bituminous shale, and were used medicinally, as stated in "Lewis's Materia Medica" for that year. More than a century ago oils were obtained by the distillation of coals, but the purification of those oils and their application to the common requirements of life have progressed but slowly, and have hardly yet reached perfection.

The first successful attempt to manufacture oils from coals in America was made by Dr. A. Gesner, who made and consumed this oil in lamps in 1846. His inventions are known as the kerosene patents, and were purchased by a company, and worked in the production of kerosene oil. Although great advances have been made in this class of apparatus, it can hardly yet be said to be so perfect as to meet the general approval of manufacturers. When once started, the production of oils from bituminous substances extended very rapidly to the chief cities of the Atlantic seaboard, as well as to those of the coal districts of the interior. The great cheapness of the oil obtained by the distillation of petroleum has, however, almost caused the coal distillation to be suspended. It will probably only be resumed when the petroleum wells cease to yield sufficient oil for the various purposes to which it is now applied. Ten years since, a calculation was made which showed that whenever crude petroleum reached an average price of 35 cents per gallon in the American markets, the coal distiller could afford to resume business.

But although at the present time there is an abundant yield of petroleum, there is an enormous amount of waste going on in the process of rendering it commercially useful. In the Dominion of Canada—to the oil wells of which we now more particularly refer—this waste arises from the present imperfect methods of manufacture, and reaches the enormous amount of 40 per cent. of the crude oil. It is estimated that the surplus crude oil of the Dominion now unsalable, reaches 350,000 barrels per annum. Besides the waste resulting from the present modes of manufacture, the finished oils produced in Canada possess a very offensive odor, owing to the presence of sulphur and arsenic in the crude oil. This has been neutralized by chemical means, but only temporarily, as the odor invariably returns, the results of the treatment not being permanent. The United States crude oil is much purer, and consequently sells at a higher price.

The great waste to which Canadian oil is subject is, however, likely to be checked, and the 40 per cent. of residuum of the ordinary makers to be profitably utilized. This anticipated saving will be effected by an improved distilling apparatus which has been invented by Messrs. Houghton and Howell, of St. Catherine's, Ontario. By means of this apparatus the waste of other makers is not only utilized, but the most valuable products are obtained therefrom. From this waste material a lubricating oil of very high quality is produced. From long trials of this oil, it is affirmed that it is not decomposed nor dried up in steam cylinders; that it is not injurious to iron; and that it will not oxidize. It, moreover, produces no acid reaction, remains perfectly limpid at 2 deg. below zero, and is not explosive nor inflammable. By the new process the arsenic and sulphur are entirely removed from the carbon oils, which are perfectly and permanently deodorized. But beyond the deodorization and conversion of the waste of other makers, Messrs. Houghton and Howell utilize the crude oil to the greatest possible extent. The largest amount obtained by other Canadian refiners from the crude is 60 per cent., and their products are then very inferior. By the patent still and machinery a yield of from 90 to 95 per cent. is obtained, whilst at the same time both the illuminating and lubricating oils possess a greater money value than do those obtained by the old mode of distillation.

The new process has been carried out in the Dominion for some little time past on a moderate scale, with success; but, being capable of wide extension, additional works are now being constructed by an English company. These works are being erected at Port Sarnia, situated upon the River St. Clair, which connects the lake of that name with Lake Huron. They are about 14 miles from the great cluster of oil wells in Petrolia, and are situated on 23 acres of land, with an extensive river frontage. There is railway communication direct between the oil wells and the works, and competing lines between the works and other parts, besides which there is navigable water available for six months of the year, thus affording direct communication with all parts of the world. The machinery for these works has been supplied by an English engineering firm, who are now superintending its erection.

We have said that the new process has been in operation for some time past, and we may here add that the products are highly appreciated in the Ontario district, where they have been largely used. The efficiency of the lubricating oil was fully proved by Mr. C. Stovin, the general manager of the Welland Railway in Canada, and who, it will be remembered, was formerly traffic manager on the London and South-Western Railway. In the beginning of the present year Mr. Stovin had the oil put to a severe test on his line. The mail car came out of the shops with new brasses fitting tightly. The wheels on one side were packed with the new oil, and those on the other side with the oil in ordinary use on the line. The journals packed with the new oil worked themselves into their proper bearings without once heating. The car ran for 13 days without a fresh supply of the lubricant, the boxes not being touched during that time. The journals on the other side heated badly, and had to be oiled every morning, and some times a mid-day dressing was found to be necessary. A trial of the oil on a locomotive engine was most satisfactory; it was carried on during very severe weather, even for Canada, and when no other oil would remain upon the machinery. The oil has also been used in England by several engineering firms with success, and bids fair to take its place as a valuable lubricant for machinery, and for railway axles. For the latter purpose especially, there is a good opening for a really efficient lubricant.

THE SEC-SYSTEM OF NOTATION.

From "The Mechanics' Magazine."

The present mode of counting by tens appears to have become so firmly established among us, that it would actually astonish some people to hear of so monstrous a thing as a change being even contemplated. Yet it is undeniably true, as Dr. Lehmann recently stated at Leipzig, that 10 is occasionally an awkward figure to deal with, and that common sense and sheer necessity have at times driven us to adopt another basis for calculation, although few have ventured to go as far as to prepare an entire reform of our numerical system. Klugel, however, mentions a case in point. Anno 1800, Herr Werneberg, the author of "Teliosadik," has laid it down as the duty of every honest man and every sensible and well-established Government to introduce, and, if necessary, to force upon the nations the dodecaic or duodecimal system. The fault found with 10 is that it is not divisible by 3 and 4, and that its divisibility by 5 is no adequate compensation for that deficiency.

Take the number 12, for instance, and it is at once apparent what facilities are afforded in its sub-division. There is the

$\frac{1}{2}$, the $\frac{1}{4}$, the $\frac{1}{3}$, and the $\frac{1}{6}$, all in round numbers, and, if 12 instead of 10 were made the basis of our numerical system, these advantages would become still more striking. The introduction of this basis would involve but few changes. New digits would have to be invented in the place of 10 and 11, and 12 would have to be written 10. It will be readily observed that the change is not beyond the realms of even practical possibility, and that the difficulties are far from being insurmountable. In fact, there are precedents in most civilized countries which would help in making the matter more familiar. The dozen, for instance, is a well-known quantity everywhere, and one which is used in more cases than in that of the number of pence making a shilling or the *Pfennige* making a *Silbergroschen.* Moreover, the words brace, stone, score, etc., remind us that the decimal system is not altogether universal. But to look at our familiar 100, and to fancy it to mean 12 dozen, is more than many of us can muster courage enough to endure, even those perhaps who without any compunction look upon a hundredweight as something different from 100 lbs.

Our numerical notation is, after all, but an acquired habit—the mode of counting which we are used to and inured in; and the elasticity of mind which would be required in order to change it for a better one, would probably be as much wanting in this as in several other quite as plausible cases of reform—the phonetic alphabet, to wit. The thing is said to look quite as well as things do occasionally in a picture, but pretty looks and practicability belong to two different spheres.

Dr. Lehmann's proposition, however, is not to introduce 12 as a basis, but 6; and in order to be better able to follow his arguments, it will be well to familiarize the matter by keeping in mind that he means to count and reckon with half-dozens instead of tens. Thus, in speaking of 80 at present, we mean 8 tens; but we might think of that figure as implying 8 dozens, or 8 half-dozens, as the case may be, the only difference being that we are used to parcel a figure out into so many tens, etc., instead of parcelling into dozens or half-dozens, etc.

It must be remarked at the outset that Dr. Lehmann reopens rather than introduces a question on the system of figures. It is stated by Libri that in the "Nouveau Traité de Diplomatique" (Paris, 1750, p. 513), mention is made of a sign for 6 which, by adding unity, expressed the subsequent figures. Peyron goes farther back than this. He states that in the Chapter-Archiv of Vercelli, this same sign for 6 is to be found on a MS. of the 9th century. If at the present day 6 were introduced as the basis of our notation, we should write it 10, and the reason why this was not done in the case of the sign just alluded to, is evidenced from the fact that the cipher 0 was not known in Christian Europe before the 13th century.

In order to facilitate the introduction of the new basis, and to avoid confusion, Dr. Lehmann proposes to change the name *sechs* into *seh*, and for argument's sake let us say that our word six be changed similarly into sec, so that we should have to count one, two, three, four, five, sec. The higher figures might be called twosec, threesec, foursec, fivesec, secsec, or sess, in accordance with the author's proposition. This latter figure would be equivalent to 36, but it would be written 1 and 2 noughts.

It is farther proposed to change the type so as to suit the new system. There would only be wanted 5 digits besides the 0, and Dr. Lehmann uses for the even figures digits with round heads, and for the odd ones digits with sharp heads. They might, for the sake of illustration, be formed out of ordinary 0, 2, 4 and 1, 3, 5, type by mutilation.

This innovation appears somewhat arbitrary, seeing that a change in the 1 would do all that is necessary.

The advantages derived from the adoption of this system are by no means imaginary. The unschooled laborer, and the village urchin, tortured alike by severe computations as high as 5×7 or 8×9, will hail the day with ecstasy which shall abolish them, and many a schoolboy will leap with joy as he hears of the advent of tables not a quarter as big as those which he now has to master in order to make his sums come without dodging.

The following shows the extent of the tables under the sec-system. In making use of the ordinary type, it must be borne in mind that 10 is equivalent to 6:

$2\times2=4$	$3\times2=10$	$4\times2=12$	$5\times2=14$
$2\times3=10$	$3\times3=13$	$4\times3=20$	$5\times3=23$
$2\times4=12$	$3\times4=20$	$4\times4=24$	$5\times4=32$
$2\times5=12$	$3\times5=23$	$4\times5=32$	$5\times5=41$

It is undeniable that the easier mode of multiplication and division resulting from the use of this system affords a guarantee for the decrease of errors in arithmetical calculations. It might, however, be argued that the length of figures will be increased in proportion with the smallness of the base; and this is true, although the inconvenience seems hardly of much account, when it is considered that up to 7775 one, and up to 60,466,175 two, additional digits only would appear under the sec-system.

In addition or subtraction, the figures to be retained or carried are limited to 4, and there are other facilities which are not altogether unworthy of notice. In counting money, *f. i.*, it is customary to take up by threes, since that number is easiest to overlook. This, however, entails the taking up of 1 in every 10, which under the sec-system is not necessary.

If, says Dr. Lehmann, the practicability of the sec-system can hardly be questioned, it is nevertheless to be feared that the way to its introduction will be barred by considerable difficulties. They are, however, by no means insurmountable. A beginning ought to be made in schools, and commerce and finance would in time have to follow suit. A Government interference on behalf of the system would also be desirable, and if one nation had fairly adopted it, the others would soon do likewise. The pains and penalties, however, attached to the labor of forcing this innovation into its proper place, would be amply rewarded by the satisfaction derived from the conviction of having delivered the coming generations from the trammels and difficulties attached to the calculations under the present decimal system.

HEAVY AND LIGHT ARTILLERY.

From "Engineering."

The satisfactory results of the firing of the 35-ton gun since its enlargement have so enchanted the Government, that we hear it is contemplated to enlarge the calibre still further. Not content with burning all the powder, obtaining low pressures and high velocities, the authorities appear to be desirous of going a step further. With what object it is hard to say, but with what result it is easy to predict, namely, the probable destruction of the gun. If, as we recently pointed out, the enlargement of the bore of the gun from 11.6 in. to 12 in. involves, as it does, a corresponding shortening of the 700 lb. projectile; which will lead to unsteadiness in flight, greater air resistance, and a reduction of penetrative power, what must the further increase in calibre enlargement do? We certainly consider the gun as already sufficiently spoiled for all purposes of correct shooting, without further experiments being tried on it in the direction of enlargement. For our own part we cannot conceive why the gun was not sent to be tried at Shoeburyness for range and accuracy before it was enlarged at all. The Committee on Explosives are well aware that when its calibre was 11.6 in. they obtained pressures of 21.7 tons per sq. in. on the projectile, 20 tons per sq. in. at the vent, and 1,353 ft. initial velocity per sec., with 120 lbs. of pebble powder. They must also know that they have not been able to obtain less than 25 ton pressures, nor more than 1,355 ft. velocities from 115 lb. charges with the gun since its enlargement. The contemplated alteration will further remove the possibility of ever rendering it a useful weapon. We hope, however, that better counsels will prevail, and that the gun will at once be sent to Shoeburyness for trial at the targets, in order to decide how far its shooting has been impaired already. The officials at the Royal gun factories are desirous that it shall be sent there, as they wish to proceed with the manufacture of the other 35-ton guns now arrested in various stages of progress pending the decision of the committee as to the most suitable calibre. We hope the committee will pause ere they again send the gun to the boring mills, for they ought to know that low pressures and high velocities at Woolwich may possibly mean want of accuracy and low penetrative power at Shoeburyness.

The 10 in. gun with which the committee are experimenting at the proof butts, Woolwich Arsenal, was recently fired with 70 lbs. of powder and a 1,000 lb. projectile.

This bolt was fitted with studs to take into the rifling of the gun, and when this piece was loaded the shot projected beyond the muzzle. Notwithstanding its great length it preserved its balance on its longer axis, and buried itself point foremost in the butt. It cut holes through the velocity screens as clean as round shot would have made. In all respects the gun came well out of this ordeal; the committee, however, have further trials in store for it.

Turning to guns of a lighter class, we have first to notice some satisfactory trials which have recently been made at Shoeburyness with the 16-pounder muzzle-loading rifled field gun. These guns weigh 12 cwt., and are rifled in 3 shallow grooves similarly to the 9-pounders. The shape, however, differs from that of the latter, there being no swell at the muzzle. The sighting is also different, occupying a central position on each of the trunnions. There also is a clever arrangement for securing the screw which tightens the rear sight. In lieu of the old chain which frequently became detached, there is an arm upon the head of the screw which catches against a button on the surface of the breech as it unwinds itself, and prevents the screw from making more revolutions than are actually requisite. The carriages, limbers, and ammunition wagons for these guns have also been improved in detail. In the recent experiments the gun charges were 3 lbs. of R. L. G. powder, and the projectiles in the first series were common shells with Royal Laboratory screw percussion fuzes, the range being 2,500 yards. Four rows of targets were set up 20 yards apart, each row being 54 ft. long, and 9 ft. high. Out of 10 rounds fired 1 was blind, the 9 giving as a result per shot on the four targets (which were placed to the rear of each other) 7.0 throughs, 2.1 lodges, and 0.9 strikes. In the second series shrapnel shells with R. L. screw percussion fuzes were fired with 3 lb. gun charges. Ten rounds were fired; one shell burst beyond the targets, and the remaining 9 gave per shot 23.4 throughs, 12.1 lodges, and 4.0 strikes. The 3d series consisted of 10 rounds with shrapnel shells, having wood time fuzes, and fired with 3 lb. powder charges as before. Two rounds proved blind, the 8 effective shots giving 36.6 throughs, 9.9 lodges, and 20.0 strikes per round. These results speak well for the range, power, and accuracy of the new 16-pounder gun, which has yet to undergo further trials at still greater ranges.

We have next to notice a new gun of a class, the introduction of which into the service has been contemplated for some time past. This is a powerful rifled howitzer, the example at Shoeburyness—the first of its kind—weighing 46 cwt., and having a bore of 8 in. diameter, with an uniform rifling of 1 turn in 16 calibres. It is mounted on a wrought-iron carriage weighing 27¼ cwt., and fitted with removable wheels, the gun being worked from a wood ground platform. This gun so far has been tried for range and accuracy of fire with common shells weighted to 180 lbs., and plugged. In the first of the two series of experiments 29 rounds were fired with charges varying from 1 lb. to 8 lbs. of R. L. G. powder. The mean ranges obtained were from 491 yards, with 1 lb. charges to 4,328 yards with 8 lb. charges. In the second series 18 rounds were fired with 8 lb. powder charges at an elevation of 40 deg. 5 min. recoil checked, the mean range being 4,283 yards, and the mean time of flight 27.0 sec. Two rounds with 10 lbs. of powder, at the same elevation as before with the recoil checked, gave as a result: mean time of flight 30.1 sec., and mean range 5,134 yards. The accuracy of the gun was fully equal to what could be expected from firing under the conditions of the above experiments.

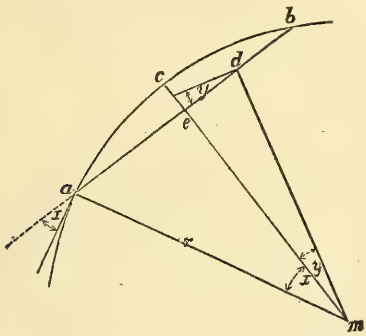
CURVES IN WAGON ROADS.

By DÖHNERT.

Translated from "Der Civil Ingenieur."

It often happens that the road engineer has to decide whether a curved street is sufficient for the carrying of long beams in respect to length of radius and width. Mere practical experience seems not to suffice in disputed cases. The familiar formula $r = \frac{l^2}{2b}$, (in which $r =$ radius, l =length of wagon, $b =$ width of road), does not give a satisfactory solution when tested. For example, suppose $l = 30$ metres, $b = 6$ m., $r = \frac{30.30}{2.6} = 75$ metres; while for the same length with a breadth of 9 metres $r = \frac{30.30}{2.9} = 50$ metres. These dimensions, as road-builders know, are much too large, for wagons of such lengths turn much sharper curves. The explanation lies in the fact that no attention has been given to the fact that the rear axle under a long beam swerves or sheers from the curve in a peculiar way.

The departure or sheering of the hind axle is a peculiarity of transport of long beams which the writer has investigated, with the following results.



If a beam is to be carried exactly round a curve (reach between axles not being taken into account), the extremities must move in the same arc of a circle. Let $a\,b$ be the beam, and $a\,c\,b$ the arc with centre m. The forward axle is at a, the other at d, and for long beams generally $b\,d = \frac{1}{4}\,a\,b$. Now, if the ends move in a circle about m, all other points of the beam, as d, must do the same. Hence the motion of d is always in the direction of the tangent; the same is true for a. Hence both the forward and the rear axles have a tangential direction, and the length from thill-pin to the forward end can be left out of account, for the direction of the thill varies little from that of the tangent.

We see then, that for given length of beam and given radius the position of the axles can be exactly determined. The angle of deviation according to simple geometrical principles is shown at the centre m, and it is $x = x$, $y = y$. But

$$\text{Tan } x = \frac{a\,e}{e\,m} \therefore e\,m = \frac{a\,e}{\tan x}$$

$$\text{Tan } y = \frac{e\,d}{e\,m} \therefore e\,m = \frac{e\,d}{\tan y}.$$

Hence

$$\text{Tan } y = \frac{e\,d}{a\,e} \tan x.$$

But

$$e\,d = \tfrac{1}{2}\,a\,e.$$

$$\therefore \text{Tan } y = \tfrac{1}{2} \tan x.$$

The angle x and y therefore have a constant ratio independent of width of road and length of beam; that is, the tangent of the rear angle is half as large as the tangent of forward angle. Generally the latter is not more than 30°, and the mean may be taken at 22°. Now

$$\tan 22° = 0.4040; \therefore \tan y = 0.2020,$$

so that $y = 11°\ 15'$, a little more than a half of 22°. The smaller x is the nearer y approaches the exact half of x.

This ratio holds if the beam is carried so that both ends move in the arc of a circle. But it generally happens that the two tangential angles differ, so that the various points of the beam deviate from the forward angle. Hence it is better to assume a mean angle smaller than the extreme angle of deviation, which in most cases is about 30°.

It is obvious that the angle x of the forward axle is of importance with reference to the length of the beam. The larger this angle the longer the beam may be, and conversely. To determine the relation:

$$\text{Sin } x = \frac{a\,e}{a\,m}$$

Since $a\,e = \frac{1}{2}\,l$ and $a\,m = r$.

$$\text{Sin } x = \tfrac{1}{2}\,\frac{l}{r}$$

$$\therefore r = \frac{l}{2 \text{ Sin } x}.$$

Suppose $x = 30°$ (the maximum)

$$r = \frac{l}{2 \text{ Sin } 30°} = \frac{l}{2}, \text{ since Sin } 30° = \tfrac{1}{2},$$

i. e. the shortest permissible radius is equal to the length of the beam.

As above stated, the angle x must be taken less than 30°. For 22°

$$r = \frac{1}{2 \text{ Sin } 22°} = \frac{1}{2\,(0.3746)} = \frac{4}{3}\,l.$$

The radius should, therefore, generally be $\frac{1}{3}$ longer than the beam, and can be shorter only in exceptional cases.

The formula shows that the radius is entirely independent of the width of roadway. Still a certain width is of course required. In what ratio this stands to radius and beam length shall be investigated hereafter.

With regard to the rear deviation-angle ; suppose that the tail-end is not $\frac{1}{4}$, but $\frac{1}{3}$ of the entire length, *i. e.*

$$b = y\tfrac{1}{3}\, a\, b.$$

Then

$$\text{Tan } y = \tfrac{1}{3} \text{ Tan } x.$$

$$\text{Sin } x = \tfrac{1}{2}\frac{l}{r}.$$

$$r = \frac{l}{2 \text{ Sin } x}.$$

Hence this equation holds for long or short tail-end, and for y large or small; in other words, the radius of the curve is the same whether the hind axle is set at $\frac{1}{3}$ or $\frac{1}{4}$ of the beam-length. This also holds if the axle is at the middle point *e;* for then $y = 0$; *i. e.*, the deviation becomes zero. Now suppose the axle at e and that the beam is of the length $a\ d = \frac{2}{3} l_1$; then $e\ d = \frac{1}{4}\ a\ d$. But $a\ d = \frac{2}{3}\ a\ b$, or $l_1 = l$. When $x = 30°$, we found $l = r$. Substituting,

$$r = \tfrac{3}{2}\, l_1;$$

i. e., the radius should be at least $1\frac{1}{2}$ times longer than the beam to prevent sheering.

Taking the forward angle at 22°

$$l = \tfrac{3}{4}\, r.$$

$$\therefore l_1 = \tfrac{2}{3} \cdot \tfrac{3}{4}\, r = \tfrac{1}{2}\, r.$$

Therefore, in general the radius must be twice as long as the beam. This will also apply to other carriages which have fixed hind axles. The racks of hay wagons measure at most 7 metres, so that the radius of the curve should be 14 metres. Such a curve would answer for an ordinary carriage road.

With reference to the width of roadway: suppose $l\ n$ to be the beam, with ends moving in an arc $l\,m\,n$, then the versine $m\ e$ of this arc is the required width. For (o being the centre of the arc)

$$\overline{l\,o}^2 = \overline{l\,e}^2 + \overline{o\,e}^2.$$

But

$$l\,o = r;\ l\,e = \frac{l}{2};\ e\,o = r - z.$$

$$\therefore r^2 = \left(\frac{l}{2}\right)^2 + (r - z)^2,$$

hence

$$z = r - \sqrt{r^2 - \left(\frac{l}{2}\right)^2}.$$

This value suffices, if the beam moves exactly as supposed. As this is in practice impossible, an excess must be allowed for play, which may be done by multiplying the value of z by some number greater than 1; for the above conditions this may be $\frac{3}{2}$. But another condition must be introduced. So far the carriage and load have been considered as a line, but as they have a necessary width, allowance must be made for this. It will be safe to increase the last value of z by a constant equal to the width of carriage, say 2.5 metres.

Hence, finally,

$$z = \tfrac{3}{2}\left\{ r - \sqrt{r^2 - \frac{l^2}{4}} \right\} + 2.5.$$

Calculating for several beam lengths and radii (the beam never being longer than radius) by the last formula we get the following table. (Dimensions in metres.)

Mean Radius.	Width for a beam-length of					
	15.	20.	25.	30.	35.	40.
15..........	5.5	..	..	.	..	..
20..........	4 7	6.5	..	..	..	..
25	4.2	5.6	7.5	..	..	..
30..........	3.9	5 1	6,6	8.5	.	..
40..........	3 6	4.4	5 5	6.9	8.6	10 5
50..........	3.3	4 0	4.9	6.0	7 2	8.8
60..........	3.2	3.8	4.5	5.4	6.4	7.6
70	3.1	3.6	4.2	4 9	5.8	6 9
80..........	3.0	3.4	4.0	4.6	5.4	6 4

These dimensions have proved sufficient in actual experiments ; and for the extreme minimum permissible, may be taken at 1 metre less.

For a straight road, r is infinitely long; hence, by the formula, $z = 2.5$ metres.

If the curve is to allow for meeting and turning out, then the width must be at least 2.5 metres greater.

It has been supposed that the street is just broad enough to let the tail-end of the beam swing round. For the case in which the forward end can swing beyond the roadway, the calculation differs a little. In this case

$$\text{Sin } x = \frac{a\,e}{a\,m}.$$

But

$$a\,e = \tfrac{3}{8}\,l, \text{ and } a\,m = r.$$

$$\therefore \text{Sin } x = \tfrac{3}{8}\,l.\ \frac{l}{r}$$

$$r = \tfrac{3}{8} \cdot \frac{l}{\text{Sin } x}.$$

For

$$x = 22°.$$

$$r = \tfrac{3}{8} \cdot \frac{l}{\text{Sin } 22°} = l.$$

But the width varies, since

$$c\,e = r - \sqrt{r^2 - (\tfrac{3}{8}l)^2} + 2.5.$$

CRITICAL EXAMINATION OF THE IDEAS OF INERTIA AND MOMENTUM.

By JAMES D. WHELPLEY.

10.—DOCTRINE OF INERTIA AS A MEASURE OF THE QUANTITY OF MATTER.

In sections 2 and 6 I have expresed only a part of the entire theory of inertia. There is, indeed, no absolute inertia, which, by its sum of equal units, shall give always the total of force and quantity of matter ; but there is a *proper* inertia of each mass, not given by induction from other matter, but determined by a similar induction in the mass itself through the reaction of its parts. This reaction is modified by the same laws of distance and quantity, internally, that regulate external influence. The reaction of a mass upon itself is definite and constant, as long as the density of the mass and the arrangement of its parts remain unchanged ; nor does it vary under external influence ; in this way constituting, in each mass, a constant base of force. In section 6 two bodies, A and B, are given, composed, A of 1, and B of 10 units of matter. In this example I did not speak of the *proper* inertia which belongs to each unit, and is independent of the external inductive forces ; but it is this proper inertia, induced by the reaction of the molecular components of the mass upon each other, that furnishes a constant base for the derivation of the forces of relation ; and if this is taken into the account it will be found that A, having the influence of the 10 units of B bearing upon it, has added to its proper inertia 10 units of induced inertias, making in all 11 dynamic elements. Its own inertia may exceed the sum of all the inductions.

But it is evident that we have no other standard for the quantity of matter in a mass, except its proper or self-induced inertia, and the quantity of this effect will determine that of gravitation. *But if a mass of matter be broken or separated in few or many parts, the sums of the proper inertias of these parts will not be equal to that of the original mass.* This was not the opinion of Newton, who maintained that inertia was inherent in the ultimate atom, and not subject to variation through internal or external inductions. There is no question here, nor need be any, of molecules or atoms ; it is not desirable to pass into the region of hypothesis while determining first principles.

11.—THEORY OF MOMENTUM.

The momentum of a body in motion is always, and at every instant of time, a definite sum of forces, which varies as the square of the velocity. A body moving freely, and consequently evolving motor force, has gained power by a sum of positive and negative increments from the point of rest. If, on the other hand, it is relatively at rest, it has arrived at that by a sum of positive and negative decrements. This principle is sustained by observation, since everything at relative rest can be shown to have been in motion. *Motion and rest are both positive and relative, and not relative alone.*—(NEWTON.)

Setting aside the directive influence of the sun, the momenta of the planets must be regarded as the result of a gradual acceleration and storing up of motor forces in their mass. They are in the condition of positive motion, irrespective of other bodies, and of relative motions, or rest, in regard to all other bodies.

It is necessary to bear in mind that each member of the solar group is itself an independent system, governed by the same laws that actuate the whole ; and, if the earth were the only body in the molecular universe, it would still have a proper inertia, created by the reaction of its particles upon each other ; and this inertia would have a definite value, although there might be no other body with which to compare and measure that value.

The motor value of the proper inertia of the earth is shown by the slow and slight movement with which it yields to the guiding influence of the sun ; its movement during one second under solar pressure is said to be only .119 of an inch.

12.—THEORY OF INDUCTION.

By whatever means the sum of inertias of a body is increased, by the same its inductive power in evolving motor force, and the motion of gravity in other bodies, is augmented. For, I have shown that the initial value of a mass is the degree of force with which it holds its first position in space, and that this mutual establishment of inertias is the primary effect of masses, and the components of masses, upon each other; while the motion of gravity (evolving motor force) is a secondary result of the formal inequalities of distance in the parts of bodies.

If two plummets are suspended at the surface of the sea, near to each other, their mutual attraction will vary with the degree of their terrestrial gravitation; and this, again, will vary with the solar distance.

Let three equal and homogeneous bodies be at unequal distances in space, and free to move; all other influences beside their mutual and self-gravitation being either null, or else equal and uniform. Each will affect the other inductively in the inverse ratios of their distances. Each of the three independent masses will have a proper and constant inertia, due to the interaction of its own particles. If this system of three bodies approaches the sun, the solar influence will be added to its proper inertias, and the mutual gravitations of the three will be intensified in the same proportion.

13.—LINEAR MOTION A FORM OF RECIPROCATION.

It appears to be impossible to discuss the continuous movements of bodies without resolving them into vibrations. I am obliged to assume the truth of this position, because I should not otherwise be in agreement with common experience.

But if, through any vibratory *molimen* of its molecular system, a body is being self-translated through space, this condition has been originated and induced by influences external to it. The movement of the solar system through space must have been slowly organized by the accumulation of minute impulses through periods of indefinite duration; for, there is no other mode, within our knowledge, by which such a result could be reached. A very small cosmical difference would be sufficient, since there is no limit in time for the accumulation of momenta.

All bodies, even balls of wet clay, or lead, are, in their interior nature, elastic. If it were not so, motion could not be communicated to them, either by gravity or by other cause.

Not only is molecular elasticity necessary to our common understanding of motion, but a body cannot even be brought to rest without illustrating all the laws of elasticity and of motor force. A mass lifted and laid upon a sustaining surface, changes its form by self-pressure in coming to rest; sensibly in large masses, as in a ship launched upon water; insensibly, but not less certainly, in smaller bodies. The "weight" of the mass, the primary motion evolved in it by the action of gravity, is finally balanced by the elastic cohesion of the molecules, and it comes to rest by means of a series of vibratory movements, in which the forces of inertia and cohesion are convertible or interchangeable.

14.—TERRESTRIAL INERTIA.

By the hypothesis of Newton, inertia is assumed to be an absolute endowment of matter, and the measure of its quantity. Gravitation, on the other hand, was taken by him to be a second force, the antagonist of inertia, and the effect of an unknown independent cause. I have assumed, on the contrary, that inertia is the primary effect of physical relation, and the motion of gravity a result of unequal inertias, due to the unequal distances of the parts of bodies.

Newton assumed that the proper inertia of a planet not only measured its quantity of matter, but was the unit and index of its gravitating force. It is necessary to acknowledge the truth of this assumption, since otherwise there would be no base of calculation for the masses of the planets. The proper inertia of the mass must be taken as a constant base.

In making this admission, I do not concede the absoluteness of the proper inertias of masses. I have shown, on the contrary, that the degree of inertia in a mass is not simply the sum of equal units composing it, but that it varies in a higher ratio than the number of units; that is to say, the reaction of the component parts is subject to the laws of distance, and the force itself is inductive.

We are compelled, as far as known conditions will take us, to assume that the mass of the earth is of a fairly uniform composition, and that the elements which compose it are distributed evenly.

The hypothesis entertained by many of an accumulation of heavy metals at the centre is untenable, from the fact, first noted by Newton, that all bodies of necessity lose "weight" or pressure toward the centre as we approach the centre, at which point, in fact, there is no "weight."

In order that the regular "concentric shell" arrangement should have place, the heavier forming the interior series, the earth must have been shaped thus from the beginning, or it is an effect of gradual deposition, or else the interior is fluid, and the arrangement has been effected by gradual separation. None of these hypotheses are consonant with what we know of the diffusion and mixture of solid, viscid, or fluid masses, or with the most probable theories of the interior heat.

Gold, iron, and other heavy metals, in very small or microscopic particles, show no tendency to aggregate in viscid or liquid slags.

Nor is it allowable, in view of actual experience, to suppose that the pressure at great depths in the earth can sensibly condense its substance; for, unless the heat evolved by such pressure can be taken up by other bodies, condensation is impossible.

We are solicited by every form of experiment to seek a more general solution of the problem of central terrestrial density, and it is to be found nowhere but in the action of the earth's mass upon itself.

In order to a better understanding, let us again notice some of the arguments and facts already given. Newton maintained that the inertia of a mass is an invariable quantity, the same in all parts of the universe, and that it is the measure of the quantity of matter, and consequently of the gravitating force of the mass, whether considered as active or passive.

I have shown that this proper inertia of masses is due, not to absolute quality, or attribute of the "ultimate particles," but is a result of the inductive reaction of the substance; and that the value of this inductive reaction, for any definite mass of sensible size, taken as a base or multiplier in calculating motor forces, would be as the square of the number of units in the mass, were it not for the law of diminution of such forces by distance. But it is obvious that these differences must have the effect to *increase the inertia —and capacity for mutual gravitation—of spherical masses regularly toward their centres.* The proper inertias of planetary masses increase regularly toward their centres, with a proportionate increase of value in gravitating force.

In other words, *the effect of the earth's mass upon itself increases its efficiency as an inductive power in the solar system.*

The "mass" of a planet is therefore determined, not only by the number of formal units of matter which compose it, but by the formal and spatial relations of those units among themselves.

But the inertias of the planets are increased by the action of the sun, and of each other, and by that of the entire cosmical system. I have shown how, in this kind, and by what laws, inertias and movements are generated and necessitated.

15.—CONDITION OF COMETS APPROACHING THE SUN.

It has been noticed that a comet approaching the sun undergoes many changes; among others, it is apparently condensed upon itself, and shows signs of an increase of central heat, and of self-pressure upon its mass. *And this might by predicted of any mass of matter approaching the sun, that its inertias and gravitations upon itself will increase proportionately.*

The comet removed in space, so far distant as not to feel sensibly the effect of the sun, will have but little more than the proper inertia and self-gravity due to its own mass. But in approaching the sun it acquires a new inertia and self-gravity, because it is becoming thereby a part of the material system of the sun, as a falling mass becomes more and more a part of the earth.

16.—INCREASE OF TERRESTRIAL GRAVITY.

When the earth is making its movement toward the sun, we must suppose that the mutual inertia, and, by consequence, the mutual gravitation of its particles, increases by solar influence. When nearest to the sun its distance may be 1-30th less than when farthest removed. Let the variation be from 30 to 29 units of distance, the inverted squares of these numbers will indicate the dynamic effects to be added to the solar-inductive force of the earth upon itself by reason of increase of solar force.

SMALL quantities of glycerine are added to paper stock to give the paper greater flexibility, but especially to give copying paper the quality of taking up color readily.

GRAPHICAL ESTIMATES FOR RAILWAY EARTHWORK.

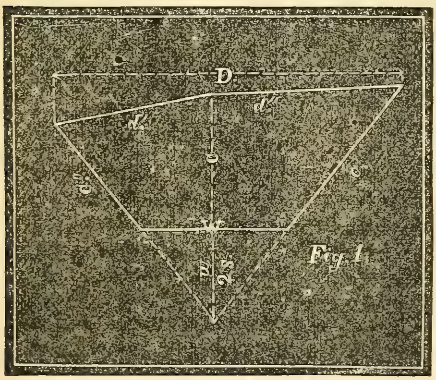
Written for "Van Nostrand's Engineering Magazine."

The multitude of devices, of more or less merit, for computing railway earthwork is an evidence, if any were needed, of the onerous character of the work and the acceptability of any relief. The following contribution to this end, by taking solidities directly from diagrams without computation from field notes kept in the usual manner, is offered to the judgment of engineers. It is believed to have at least the merit of novelty.

The method consists essentially of three diagrams, viz.: for sectional areas of thorough-cut sections, for sectional areas of side-hill sections, and for a correction to be applied to end-area solidities, to give the true solidity by the prismoidal formula.

We will first obtain the diagram for sectional areas of thorough-cut sections.

In any cross-section let



c = the centre cut.
c' and c'' = side cuts.
d' and d'' = D = width on surface.
w = width of road-bed.
s = ratio of slope, 3-2, 5-4, etc.
A = area.

Then the area will be given by the equation:

$$A = \frac{D\left(c + \frac{w}{2s}\right)}{2} - \frac{w^2}{4s}, \text{ or}$$

$$A = \frac{c}{2}D + \frac{w}{4s}D - \frac{w^2}{4s} \ (1).$$

It is evident that letting $A = A + A_2$ equation (1) is equal to the sum of the two equations.

$$A = \frac{c}{2}D \ (2), \text{ and}$$

$$A_2 = \frac{w}{4s}D - \frac{w^2}{4s} \ (3),$$

both of which are the equation of straight lines, taking A and D as the variables y and x respectively; and that the value of equation (2) is independent of the particular road-bed and slope, and that of equation (3) of the depth of the centre cut. Consequently, if, laying off successive values of D along the axis of x, and of A along the axis of y, we plot equation (2) above the axis of x for successive values of c, and equation (3) below it for the different combination of values of w and s which occur in practice, we obtain a diagram from which the area of any cross-section of any variety of road-bed and slope can be obtained, by scaling along the line x = D from the line above the axis of x representing the given centre cut to the line below it representing the given combination of a road-bed and slope. Such a diagram, giving areas for any kind of railway earthwork having regular slopes, has been constructed and used, but involves considerable labor and care in drawing, and to be of practical use should be engraved. The object of the present paper will be best met by giving the practical details of construction for a simple modification which is applicable to but one combination of road-bed and slope, but dispenses with the use of the scale and can be drawn on a sheet of cross-section paper in three or four hours, with very little calculation.

We will suppose a diagram is required for a road-bed of 14 feet and slopes of 1½ to 1, on a sheet of 16 × 20 engraved cross-section paper graduated to tenths of an inch. Lay off along the bottom of the sheet successive values of D to a scale of 2 ft. to 1 in., the fine lines thus representing differences of 0.2 in the value of D. If we begin at the smallest possible value, 14, the last given will be 54 ft. Also, lay off up the sides of the sheet successive values of A to a scale of 50 ft. to an inch, the fine horizontal lines thus representing differences of 5 ft. in area.

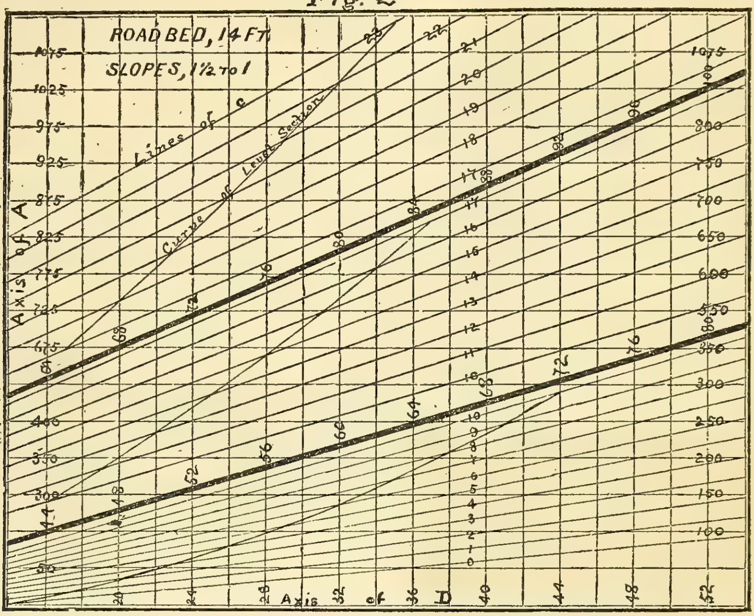
Now take D = 50 and solve equation (1) for the case $c = 0$. The first member disappears and we have

$$A = \frac{w}{4s} D - \frac{w^2}{4s} = 84 \quad (4.)$$

Lay off 84 on the diagram on line D=50. Perform the same operation, taking D = 20, when it is found A = 14. Lay off 14 on line D = 20 and through the points thus found draw a straight line which will also pass through the point D = 14, A = 0. The remaining work is almost mechanical, for since the value of c only af-

Diagram of Thorough-cut Sections.

Fig. 2



fects the first member of equation (1), if $c = 0.2$ equation (4) becomes

$$A = \frac{0.2\,D}{2} + 84 = 5 + 84;$$

if $c = 0.4$ it becomes $A = 10 + 84$, etc., increasing by $\frac{D}{10}$ for every increase of 0.2 in c. Lay off then on line D=50, successive values of c varying by 0.2, *i. e.*, 89, 94, 99, 104, etc., up to say $c = 10$ ft., and in the same way on line D = 20, 16, 18, 20, 22, etc., and passing straight lines through the points thus found the diagram is complete to 10 ft.

But in continuing for cuts of more than 10 ft., the smallest value of D likely to occur in practice is about 42 ft., so that it superfluous to give smaller values on the remainder of the diagram. Accordingly, draw a heavy line just above and parallel with line $c = 10$ and lay off along it new values of D running from 42 to 82. Solve equation (1) again with $c = 10$ and D = say 50 and 80, and—letting the horizontal lines represent new values of A as found convenient—plot the result.

Then proceed as before, laying off $\frac{D}{10}$ successively up to say 17 ft., when a new heavy line is drawn, new values of D laid off, say from 62 to 102, and proceeding as before, the sheet is completed, extending up to 22 feet for any variety of surface. In continuing for higher values of c on other sheets, take the 16-in. side as the axis of x and lay off $\frac{D}{20}$ for single tenths. The method is otherwise the same.

It is well as a check to lay off values of c on one or more intermediate lines, and a smooth and unwarped sheet should be selected. Lines representing even values of c should be made prominent, and values of all the lines put at convenient intervals over the face of the diagram.

The diagram proper being finished, the "curve of level section" should be drawn on, that is, the curve of the equation $A = w\,c + c^2\,s$. This can be done without calculation, by considering that in a level section, if c be increased by 1, D it increased by 2 s. Thus in the diagram described, the curve will pass through the points, $c=0$, $D=14$; $c=1$, $D=17$; $c=2$, $D=20$, etc.

As a practical example, required the area of the following cross-section:

$$\frac{13.0}{-4.0} \text{——} 7.2 \frac{24.7}{-11.8}.$$

Taking at the bottom of the sheet the line D= 37.7 (13.0 + 24.7), follow it up till it intersects the inclined line $c=7.2$. Place the needle-point there and read off the horizontal lines the area = 191 ft.

Required the height of an equivalent level section to the above. Follow horizontally the line A= 191 to its intersection with the curve of level section, and read off the height required from the inclined centre cut lines, = 7.55. Suppose, by error, 7.2 above given 9.2. The point of intersection found will then lie above and within the curve of level section, its position indicating that the centre height is disproportionately great. The query at once arises whether this is correct. The ratio of c to D is always indicated by the relative position of the point obtained, and errors will thus be often detected which in computation would pass unnoticed. Areas are easily taken off to the nearest half foot if desired.

Where the ground is so irregular that intermediate side levels become necessary, it will be found most convenient to take off the area as usual, neglecting the intermediates, subsequently plotting the surface lines only of the cross-section, to obtain the area to be added to, or subtracted from, the result given by the diagram.

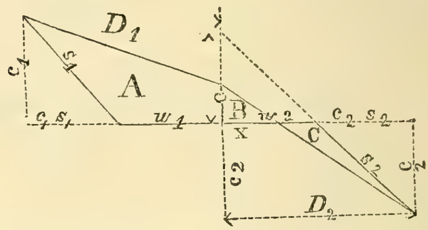
We will now take up the second diagram, providing for the cases of side-hill cross-sections, to which the previous diagram does not apply.

In any side-hill section

Let c = the centre height.
c_1 = side height in "thorough-cut" side.
c_2 = " " "side-hill" side.
D_1 and D_2 = corresponding distances cut.
w_1 and w_2 = half widths of road-bed.
s_1 and s_2 = ratio of slope in each case.
A, B, and C = parts of section as lettered in Fig. 3, *or* the areas thereof.

Since c_1 and c_2 are each set for a different road-bed and slope, the section shown in Fig. 3 in reality consists of two separate and mutually independent parts, A and B C, having the common centre height, c. The side B C again consists of two parts, B and C, one in excavation and one in embankment, which are given separately; and A and B then combined as will be seen. All areas will be expressed in terms of D and c, as in the thorough-cut diagram.

Fig.3.



We will first obtain the formulæ of area. The trapezium A presents no difficulty, its equation being only a modification of that of a thorough-cut section. With the above nomenclature.

$$A = \frac{\left(c+\frac{w_1}{s_1}\right)D_1}{2} - \frac{w_1^{\,2}}{2\,s_1}$$

or

$$A = \frac{c}{2}D_1 + \frac{w_1}{2\,s_1}D_1 - \frac{w_1^{\,2}}{2\,s_1} \quad (5.)$$

For the triangle B_1—if we let x = its base, we have $B=\frac{c\,x}{2}$. But, by a proportion evident from the figure,

$$x = \frac{c\,D_2}{c+c_2} = \frac{c(w_2+c_2\,s_2)}{c+c_2};$$

substituting this value we obtain

$$B = \frac{c^2\,(w_2+c_2\,s_2)}{2\,(c+c_2)} \quad (6.)$$

For the triangle C, we have

$$C = \frac{(w_2-x)\,c_2}{2} = \frac{\left(w_2 - \frac{c\,(w_2+c_2\,s_2)}{c+c_2}\right)}{2}c_2,$$

and reducing

$$C = \frac{c_2^{\,2}\,(w_2-c\,s_2)}{2\,(c+c_2)} \quad (7.)$$

The above equations (6) and (7) are expressed in terms of c and c_2. They can now be expressed in terms of c and D_2, in terms of which the diagrams are to be constructed, by simple substitution, since

D_2 is a function of c_2; but the above forms are more simple and answer equally well, as will be seen.

We have now to construct the diagram from the formulæ. It must evidently consist of separate and subordinate diagrams for A, B, and C. In each case values of D are laid off horizontally, and of area vertically, and the equation plotted for successive values of c. We will assume as limiting dimensions a maximum value of 12 ft. for c_1 and of 6 ft. for c and c_2.

The diagram of A, which comes first in order, consists of right lines, and is the same in principle as the thorough cut diagram. Solve Eq. (5) for the case $c = 0$, letting $D_1 = 10$ and 20 successively. Plot the results on the proper vertical lines of D_1, above the points thus obtained lay off $\frac{D}{4}$ continuously, for differences of 0.5 in the value of c, up to $c = 6$, and pass straight lines through the points obtained.

The equation of B and of C is that of a curve, to plot which, points on each line of c must be determined at intervals. In practice, since the curves are not sharp, points determined for even feet of c_2 are sufficiently close; and since these triangles are always small, only lines of c for even feet need be drawn. The preliminary computation—thus reduced to small limits—is done most easily by making a rough pencil table with columns for each of the different terms of the formula, for each value of c_2 from 1 to 6. The last column of each of these tables—consisting of the areas sought—is then copied into a second table of results, and headed, *not* with the value of c_2, under which it was computed, but with the *value of* D_2 *corresponding to it.* These tables are given below for four cases of common occurrence.

TABLES USED IN CONSTRUCTING DIAGRAMS OF B AND C.

Centre ht.	*Areas of B.*							$w = 7$ $s = 1\frac{1}{2}$ to 1. *Areas of C.*						
	D=7	D=8.5	D=10	D=11.5	D=13	D=14.5	D=16	D=7	D=8.5	D=10	D=11.5	D=13	D=14.5	D=16
0	0.0	0 0	0.0	0 0	0 0	0 0	0.0	0.0	3.5	7.0	10.5	14 0	17.5	21.0
1	3 5	2.1	1.7	1.4	1.3	1.2	1.1	0.0	1.4	3.7	6.2	8.8	11 5	14.1
2	7 0	5.7	5.0	4 6	4.3	4 1	4.0	0.0	0.7	2.0	3.6	5.3	7.1	9 0
3	10.5	9.6	9 0	8.6	8.4	8 2	8 0	0.0	0.3	1.0	1.9	2.9	3.9	5.0
4	14.0	13 6	13.3	13.1	13 0	12.9	12.8	0 0	0 1	0 3	0.6	1.0	1 4	1.8
$4\frac{2}{3}$	16.3	16.3	16.3	16.3	16 3	16 3	16.3	0.0	0.0	0.0	0.0	0.0	0.0	0 0

Centre ht.	*Areas of B.*							$w = 7\frac{1}{2}$ $s = 1\frac{1}{2}$ to 1. *Areas of C.*						
	D=7.5	D=9.0	D=10.5	D=12.0	D=13.5	D=15.0	D=16.5	D=7.5	D=9.0	D=10.5	D=12.0	D=13.5	D=15.0	D=16.5
0	0.0	0.0	0.0	0.0	0.0	0.0	0 0	0·0	3.8	7.5	11.3	15.0	18 8	22 5
1	3.8	2.2	1.7	1.5	1 4	1.3	1.2	0·0	1 5	4.0	6.8	9 6	12.5	15.4
2	7.5	6 0	5.2	4 8	4 5	4.3	4 1	0·0	0.7	2 2	4.1	6 0	8 0	10.1
3	11 3	10.1	9.5	9.0	8 7	8.5	8.3	0.0	0 3	1.2	2.3	3.4	4 7	6.0
4	15.0	14.4	14.0	13 7	13 5	13.3	13.2	0 0	0 1	0 5	1 0	1.5	2.1	2 7
5	18.8	18 2	18 8	18 8	18.8	18 8	18.8	0.0	0.0	0.0	0.0	0 0	0.0	0.0

Centre ht.	*Areas of B.*							$w = 9$ $s = 1\frac{1}{2}$ to 1. *Areas of C.*						
	D=9	D=10.5	D=12	D=13.5	D=15	D=16.5	D=18	D=9	D=10.5	D=12	D=13.5	D=15	D=16.5	D=18
0	0.0	0 0	0.0	0.0	0.0	0 0	0 0	0 0	4.5	9.0	13.5	18 0	22.5	27.0
1	4.5	2 6	2.0	1.7	1.5	1.4	1.3	0.0	1.8	5.0	8.4	12.0	15.6	19.3
2	9 0	7.0	6.0	5.4	5.0	4.7	4.5	0 0	1.0	3.0	5 4	8.0	10.7	13.5
3	13 5	11.8	10 8	10.1	9.6	9.3	9.0	0.0	0.6	1 8	3.5	5 1	7.0	9 0
4	18.0	16.8	16 0	15.5	15 0	14 7	14.4	0.0	0.3	1.0	1.9	3 0	4.2	5.4
5	22 5	21.9	21.4	21.1	20 8	20.6	20.5	0.0	0.1	0.4	0 8	1.3	1 9	2.5
6	27.0	27.0	27.0	27.0	27.0	27.0	27.0	0.0	0.0	0 0	0.0	0.0	0.0	0.0

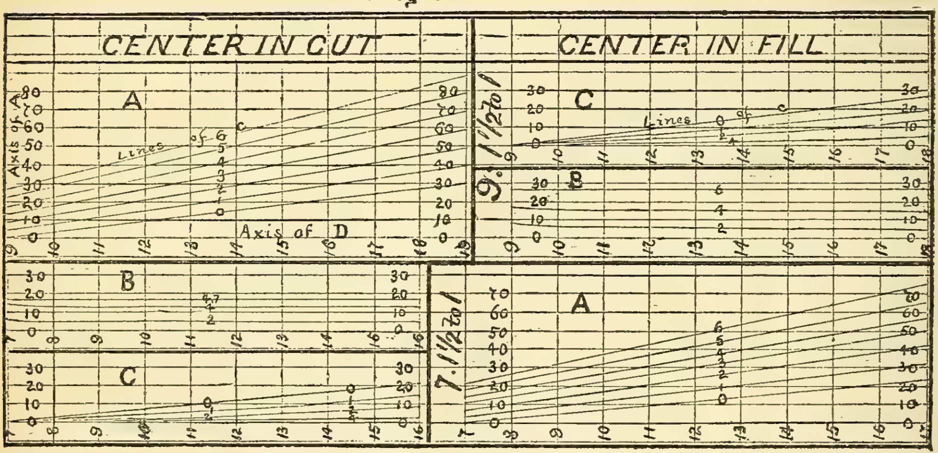
Centre ht.	*Areas of B.*						$w=10$ $s=1\frac{1}{2}$ *to* 1.					*Areas of C.*		
	D=10	D=11.5	D=13.0	D=14.5	D=16	D=17.5	D=19.0	D=10	D=11.5	D=13.0	D=14.5	D=16.0	D=17.5	D=19.0
0	0.0	0.0	0.0	0 0	0.0	0.0	0.0	0.0	5.0	10 0	15.0	20 0	25 0	30 0
1	5.0	2.9	2.2	1.8	1.6	1.5	1.4	0.0	2.1	5.7	9.6	13.6	17.7	21 9
2	10.0	7.7	6 5	5.8	5 3	5.0	4.8	0.0	1.2	3.5	6 3	9.3	12.5	15.6
3	15.0	12.9	11 7	10 9	10.3	9.8	9.5	0.0	0.7	2.2	4 1	6 3	8.6	11.0
4	20.0	18.4	17.3	16.6	16 0	15.6	13.6	0 0	0.4	1.3	2 6	4 0	5 6	7.2
5	25 0	24.0	23 2	22.7	22.2	21 9	21 6	0.0	0 2	0.7	1.4	2.2	3.1	4.1
6	30.0	39.6	29.3	29 0	28.8	28 6	28.5	0.0	0 1	0.3	0.5	0.8	1 1	1.5

It must be borne in mind in calculating these tables that the greatest possible value of c is $\frac{w_2}{s_2}$, which distance, laid off on the centre height c prolonged, marks its insection with the slope s_2. The triangle B then has its maximum value,

$$B=\frac{w_2{}^2}{2s_2} \text{ and } C=0.$$

Also, when c has its minimum value, 0, the equation of C reduces to $C=\frac{w_2\ c_2}{2}$, and similarly when $c_2=0$, $B=\frac{w_2\ c}{2}$.

Fig. 4



The construction of the diagram from these tables is shown in Fig. 4, a reduction to half scale of a side-hill diagram for a road having 14 and 18 ft. road-beds and all slopes $1\frac{1}{2}$ to 1. To construct this take a piece of cross-section paper 6×15 in., graduated to tenths, and beginning in the lower left hand corner lay off values of D from 7 to 16, and plot the table of c for the case $w=7$, $s=1\frac{1}{2}$ to 1. Since the area of C is in inverse ratio to c, the line $c_{,}=0$—a right line passing through the origin—is the highest, and the curved lines, $c=1, 2, 3$, etc., come consecutively below. Pass these lines through the points obtained by plotting the table, and above the diagram thus obtained construct the diagram of B for the same case. Here the line

$$c=\frac{w}{s}=4\tfrac{2}{3}$$

—a right line parallel with the axis of D—is the highest, and the flat and nearly parallel curved lines $c=4, 3, 2$, etc., come consecutively below. At the end of these two diagrams construct the diagram of A for the same case, and above the three diagrams now completed, construct in inverse order, as seen in Fig. 4, the three diagrams for the case $w=9$, $s=1\frac{1}{2}$ to 1. As thus arranged the first *vertical* column of 3 diagrams gives the areas of A, B, and C, when the centre, c, is in cut, and the second when in fill. Head the columns correspondingly, and place values of lines, etc., conveniently over the face of the diagram. If a third or fourth class of road-bed occur on the work, plot its diagrams above or below the two shown in the figure and use the pair applying to the given cross-section.

The diagram as thus constructed is used with equal facility with the thorough-cut diagram, and since the general arrangement of both is similar no special care or thought is required in passing from one to the other. Thus, in taking off areas from the cross-section book a side-hill section is met with, as

$$\frac{18.4}{+6.3} + 1.6 - \frac{12.4}{3.6}.$$

The assistant—always beginning on the thorough-cut side of the section—calls off "side-hill, 1.6 cut, 18.4." Take the side-diagram under column "centre in cut," and beginning always with the diagram of A, follow up line D = 18.4 to its intersection with line c = 1.6 which is found to be on the horizontal line A = 43. The assistant then calls "12.4." Taking the diagram of B immediately below, follow the vertical line D=12.4 to its intersection with the curved line c = 1.6, obtaining 3 as the area of B, which the assistant adds to the 43, and sets down in the cut column of areas, while from the same notes of D = 12.4, c = 1.6, the area of the third triangle C is taken from its diagram and placed in the fill column of areas, and the work is proceeded with. In practice the delay for side-hill cross-sections, even when very frequent, is inappreciable.

The end area solidities which have next to be sought can be obtained from the tables in common use, or still better, by an improvement due to Mr. Chas. A. Smith, C. E., Asst. Prof. of Civil Engineering, in Washington University, can be obtained directly from the diagrams, by constructing them to give areas multiplied by the factor $\frac{100}{54}$, when the solidity for a full station is given by simple addition. This involves no change in the construction of the diagrams except that the scale of A $\times \frac{100}{54}$ should be 100 to an inch instead of 50, and that in the thorough-cut diagram values of c should be laid off, for convenience, on lines D = 54, 27, etc., to avoid fractional increments. The requisite changes in the tables for constructing the side-hill diagram are easily made.

We have now reached the third step in the process, the determination of the true solidity by the prismoidal formula, which is obtained by means of a connection to be applied to the end-area solidity. Several methods on this principle are already in use and can be used if preferred, but as a rule are approximate only. The following formula and diagram, by Mr. Chas. A. Smith, C. E., gives an absolutely correct result, and in terms of the same dimensions, D and c, which have been already employed in the previous diagrams.

In any prismoid, letting A and A^1 = the areas of the end-sections, we have by Eq. (1), the basis of the thorough-cut cross-section diagram.

$$A = \frac{c}{2} D + \frac{w}{4s} D - \frac{w^2}{4s}, \qquad (8.)$$

and

$$A^1 = \frac{c^1}{2} D^1 + \frac{w}{4s} D^1 - \frac{w^2}{4s} \qquad (9.)$$

Adding Eq. (8) and (9) together, dividing by 2 and multiplying by l we obtain as the end-area solidity

$$S_E = \left\{ \frac{c}{2} D + \frac{c^1}{2} D^1 + \frac{w}{4s}(D+D^1) - \frac{2w^2}{4s} \right\} \frac{l}{2},$$

or

$$S_E = \left\{ \frac{3c}{2} D + \frac{3c^1}{2} D^1 + \frac{3w}{4s}(D+D^1) - \frac{6w^2}{4s} \right\} \frac{l}{6} \qquad (10.)$$

We have now to obtain the *true* solidity, = s, to do which we must first obtain the area of the middle section, every dimension of which is equal to the half sum of the corresponding parts of the end sections, consequently

$$A_M = \frac{c+c^1}{4} \frac{D+D^1}{2} + \frac{w}{4s} \frac{D+D^1}{2} + \frac{w^2}{4s} \qquad (11.)$$

By the prismoidal formula $S = (A + A^1 + 4A_M)\frac{l}{6}$, or substituting the different values of A as given in Eq. (8), (9) and (11), and placing similar terms together

$$S = \frac{c}{2} D + \frac{c^1}{2} D^1 + (c + c^1) \frac{D + D^1}{2} + \frac{3w}{4s}(D + D^1) - \frac{6w^2}{4s} \qquad (12.)$$

Subtracting Eq. (12) from (10), terms containing w and s disappear, and we have

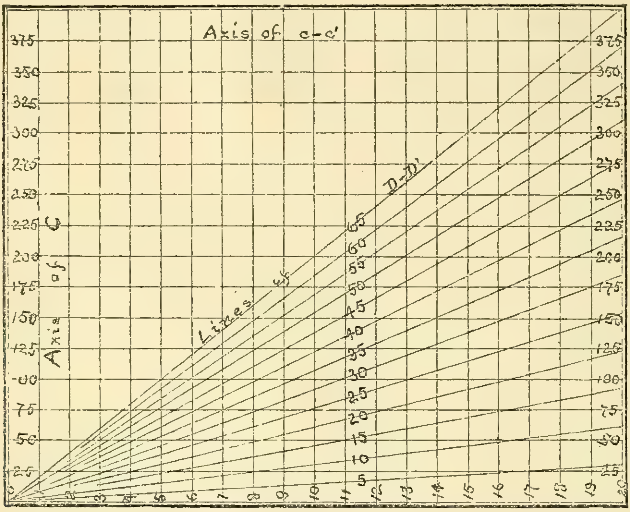
$$S_E - S = \frac{cD + c^1 D^1 - cD^1 - c^1 D}{2} \frac{l}{6},$$

or, letting $S_E - S = C$.

$$C = (c - c^1)(D - D^1)\frac{l}{12} \qquad (13.)$$

In diagramizing, let $l = 100$ ft., and divide the last member by 27 to give results in cubic yards, giving the equation the form $C = \frac{D - D^1}{3.24}(c - c)$. Let $c - c^1 =$ the variable x, and on a sheet of 16×20 cross-section paper lay off values for it horizontally to a scale of 1 ft. to an inch. Let $C =$ the variable y, and lay off values for it vertically to a scale of 20 or 25 cubic yards to an inch, and—theoretically—plot the equation for successive values of $D - D^1$. Practically, this is done by laying off continuously on a given line of $c - c^1$, the corresponding values of C for successive increments of 1 ft. in the value of $D - D^1$. If we select those lines of $c - c^1$, which are multiples of 3.24, *e. g.*, 6.48, 12.96, 19.44, these increments become integral for the cases supposed, being 2, 4, 6, respectively,

Fig. 5



and can be laid off almost mechanically. Pass right lines through the points thus obtained, which also pass through the origin in the left hand lower corner, and the diagram is complete, applying, as is evident from the formula, to any combination of road-bed and slope.

To use the diagram, we have already obtained the values of D and D^1, in getting end-area solidities. The difference between these, and also the value of $c - c^1$, we obtain mentally, or by previous subtraction, and finding, as in the other diagrams, the point of intersection of the lines which represent these data, the correction for a full station of 100 ft. is given by the horizontal line passing through it, set down in pencil in a column for the purpose, and subsequently inked, in taking the proper fractional parts for fractional stations. The total amount of these corrections for each cut or for the whole division is then obtained and subtracted from the end-area solidity. There is nothing gained by applying the correction to each individual solid, and by this method the work can be done at any time when leisure offers, with great advantage to the probable accuracy.

It is thought that this system of computation will be found, on trial, to offer considerable advantages. Graphical methods have been little used for this purpose, and the diagrams may seem complicated in construction, but it is believed that their practical use will be found to be simple and direct, and to contain in a high degree accuracy and speed. The error of observation need never exceed ½ sq. ft. of area, considerably within the probability of error from neglecting half-tenths in the field work, and similar causes, and beyond this the results are mathematically correct. The seemingly greater precision of tables or computation, it is needless to say, is purely fictitious. As the work is a simple matter of eyesight, and the result in each case is given at once, the work is rapid and not fatiguing, and careless errors are very rare. End-area solidities can be taken off by two men, with ordinary diligence, at the rate of 400 cross-sections per hour.

THE TEMPERATURE PRODUCED BY SOLAR RADIATION.

From "Nature."

By J. ERICSSON.

Sir Isaac Newton determined the intensity of solar radiation by observing the increment of temperature of dry earth on being exposed to the sun. In the latitude of London at midsummer, dry earth acquires a temperature of 150 deg. in the sun at noon and 85 deg. in the shade, difference about 65 deg. Fahr. This difference Sir Isaac Newton regarded as a true index of the intensity of solar radiation; hence his celebrated demonstration proving that the comet of 1680 was subjected to a temperature 7,000 times higher than that of boiling water (212 deg. $\times$ 7,000 = 1,484,000 deg. Fahr.*) The comet when in its perihelion being within one-third part of the radius of the sun from his surface, we have to add the diminution of temperature, 0.44, attending the dispersion of the rays in passing through the solar atmosphere and the remainder of the stated distance from the sun. Accordingly, the demonstration showing that the comet of 1680 was subjected to a temperature 7,000 times higher than that of boiling water, establishes a solar temperature exceeding 2,640,000 deg.; and if we add 0.21 for the retardation of the rays in traversing the terrestrial atmosphere, it will be found that the temperature deduced from the experiments with incandescent radiators, and our actinometer observations, differs scarcely $\frac{1}{5}$ from that roughly estimated by the author of the "Principia." In order to comprehend fully the merits of the method of determining solar intensity conceived by his master mind, let us imagine an extended surface of dry earth, one half of which is shaded, the other half being exposed to the sun. Dry earth being a powerful absorbent and radiator, and at the same time a bad conductor, the central portion of the supposed surface evidently cannot suffer any loss of heat by lateral radiation; while the nonconducting property of the material prevents loss by conduction laterally or downwards. Consequently, no reduction of temperature can take place excepting by radiation in the direction of the source of the heat. Removing the shade, during an investigation, it will be found that, notwithstanding the uninterrupted radiation of the exposed substance upwards, the intensity will gradually increase until an additional temperature of about 65 deg. Fahr. has been acquired. Indisputably this increase of temperature is due to unaided solar radiation. Evidently the accidental interference of currents of air need not be considered. Besides, if the dry earth is confined within a vacuum, such interference may be entirely obviated. It is scarcely necessary to point out that the generally adopted mode of measuring the sun's radiant heat by thermometers, is in direct opposition to the principle involved in the method under consideration. The meteorologist, in place of preventing the bulb from radiating in all directions and guarding against loss of heat by convection, puts his thermometer on the grass, or suspends it on a post, one half of the convex area of the bulb receiving the sun's radiant heat, while the other half is permitted to radiate freely, the whole being exposed to the radiation from surrounding objects and to the refrigerating influence of accidental currents of air, in addition to the permanent current produced by the ascending heated column above the bulb. This explains the cause of the perplexing discrepancies in meteorological records. The extent of the diminution of intensity of solar radiation occasioned by cold air acting on the bulb, and by the latter radiating freely in all directions, is demonstrated in the most

* Sir Isaac Newton has been criticised for comparing the temperature to that of red-hot iron. "a term of comparison indeed of a very vague description," it is said in "Outlines of Astronomy." This criticism is far from being correct, since the demonstration clearly shows what is meant by the term red-hot, viz., a temperature 3.5 times that of boiling water. The reference to red-heat, exceeded "2,000 times," was evidently intended to furnish some adequate notion of the inconceivably high degree of temperature involved in the computation.

conclusive manner by the result of observations made with the instrument described by Père Secchi in his recent work "Le Soleil" (p. 267). "During a great number of observations made at Rome," says the author, "the difference between the two temperatures (that indicated by the thermometer exposed to the sun and that of the surrounding casing) was 12.06 deg. (21.70 deg. Fahr.); during days when the sky was clearer, it rose to 14 deg." Consequently, the highest temperature indicated by the instrument referred to, was 25.2 deg. Fahr., against 66.04 deg., which is the true maximum solar intensity in the latitude of Rome. It will be seen then, that, by exposing the bulb of the thermometer in the manner pointed out,

TABLE A.

Showing the Temperature produced by Solar Radiation at Noon, for each degree of Latitude, when the Earth is in Aphelion. Northern Hemisphere.

	Latitude	Solar intensity at Noon.	Latitude	Solar intensity at Noon.	Latitude	Solar intensity at Noon.	Latitude	Solar intensity at Noon.	
	Deg.	Fah.	Deg.	Fah.	Deg.	Fah	Deg.	Fah.	
Equator........	0	65 30	24	67 20	49	64.95			
	1	65.45	25	67.19	50	64 77			
	2	65.60	26	67 18	51	64.58			
	3	65.75	27	67.17	51.28	64.48	....	....	Greenwich.
	4	65 89	28	67 14	52	64.38	72	58 69	
	5	66.02	29	67.10	53	64.17	73	58.31	
	6	66.15	30	67.05	54	63 96	74	57.92	
	7	66 27	31	66 99	55	63.74	75	57.52	
	8	66.39	32	66.93	56	63.51	76	57.10	
	9	66 49	33	66 87	57	63.28	77	56.67	
	10	66.58	34	66 80	58	63 04	78	56 24	
	11	66.66	35	66 73	59	62 79	79	55.79	
	12	66.73	36	66.66	60	62.53	80	55.32	
	13	66.80	37	66.58	61	62.25	81	54.84	
	14	66.87	38	66.49	62	61.96	82	54.35	
	15	66.93	39	66 39	63	61 65	83	53.84	
	16	66 99	40	66 27	64	61.34	84	53 32	
	17	67.05	41	66 15	65	61.03	85	52 78	
	18	67.10	42	66.02	66	60 72	86	52 23	
	19	67.14	43	65.89	66 30	60.57	....	....	Arctic Circle.
	20	67.17	44	65.75	67	60 41	87	51.68	
	21	67 18	45	65.60	68	60.09	88	51.11	
	22	67 19	46	65.45	69	59.76	89	50.52	
	23	67.20	47	65.30	70	59 42	90	49.91	North Pole.
Tropic of Cancer	23 30	67.20	48	65.13	71	59.06			

TABLE B.

Showing the Temperature produced by Solar Radiation in the Earth's orbit; also the gradual Diminution of Temperature during the first half, and the gradual Increment of Temperature during the second half-year:

Dates.	1st.		5th.		10th.		15th.		20th.		25th.	
Months.	Max.	Diff.	Max.	Diff.	Max.	Diff.	Max.	Diff.	Max.	Diff.	Max.	Diff.
	Fah.	Fah.	Fah.	Fah.	Fah.	Fah.	Fah.	Fah	Fah.	Fah	Fah.	Fah.
January..........	90 72	5 88	90.70	5.86	90.67	5 83	90.62	5.78	90.54	5.70	90 44	5.60
February	90 28	5.44	90.16	5 32	90.01	5.17	89 83	4.99	89.64	4.80	89.43	4.59
March...........	89 27	4 43	89.09	4.25	88 86	4 02	88.62	3 78	88.37	3 53	88.12	3.28
April............	87.77	2.93	87 57	2 73	87 32	2 48	87.07	2.23	86.83	1.99	86.59	1.75
May.......... ...	86.32	1.48	86.15	1.31	85.95	1 11	85.76	0.92	85 58	0.74	85.43	0.59
June	85.22	0.38	85.13	0 29	85.03	0.19	84.96	0 12	84 90	0.06	84.86	0 02
July............	84 84	0.00	84 85	0.01	84 87	0 03	84.92	0.08	84.99	0.15	85.07	0.23
August..........	85.22	0.38	85.34	0.50	85.49	0.65	85.65	0.81	85.83	0.99	86 03	1.19
September.......	86.32	1.48	86.50	1.66	86.73	1.89	86.97	2.13	87 22	2 38	87.47	2.63
October.........	87.77	2.93	87 97	3.13	88 22	3.38	88.47	3.63	88.71	3.87	88.95	4.11
November.......	89.27	4 43	89.43	4.59	89.64	4 80	89.83	4 99	90 01	5.17	90.16	5.32
December.......	90.33	5.49	90.42	5.58	90.52	5.68	90.61	5.77	90.66	5.82	90.70	5.86

TABLE C.

Temperatures produced by Solar Radiation, June 26, 1871, compared with the Temperatures entered in the Table constructed 1870, for corresponding Zenith distances. Mean Discrepancy = 0.26° Fahr.:

	Zenith Distances—Degrees.								
	57	58	59	60	61	62	63	64	65
	Fah.	Fah.	Fah.	Fah.	Fah.	Fah.	Fah.	Fah.	Fah.
Observations June 26, 1871............	55.64	55.00	53.83	53 51	53 41	52.76	52.23	51.70	51 27
Table of 1870	55.09	54 60	54.10	53.58	53.05	52 50	51 90	51 40	50.81

it is possible to reduce the temperature produced by solar radiation to 0.38 deg. of the actual temperature.

It will be proper to observe with reference to the accompanying tables—constructed in accordance with the result of investigations continued winter and summer during three years—that the opinion expressed by the Director of the Roman Observatory, respecting solar intensity at different seasons, is wholly at variance with the facts established by my numerous observations. The question was raised last summer whether the high temperature during the "heated term" would not charge the atmosphere with an additional amount of vapor capable of retarding the passage of the heat rays, thus rendering the figures entered in my tables to some extent unreliable. Accordingly, during the solstice, June 26, 1871, the sky being very clear, the actinometer was put in operation for the purpose of ascertaining with critical nicety whether the atmosphere which had been loaded with vapor for several weeks previously, possessed any unusual property tending to check the heating power of the sun's rays. The observations were made late in the afternoon under great zenith distance and increased atmospheric depth, in order to subject the heat rays to an additional retardation from the supposed vapors. The result is recorded in Table C, by which it will be seen that the reduction of temperature was only 0.26 deg. Fahr., a difference too small to call for any explanation. The result of the observations made during midwinter are equally conclusive with reference to the permanency of solar energy at all seasons. Among others may be mentioned that of January 17, 1871, the zenith distance being 61 deg. 30 min., the actinometer remained perfectly stationary at 58.73 deg. Fahr., from 12h. 10m. to 12h. 20m., p. m. The table just referred to shows that on June 26, 1871, the actinometer indicated 53.08 deg. when the sun's zenith distance was 61 deg. 30 min. Hence during midwinter the temperature proved to be 58.73 deg. — 53.08 deg. = 5.65 deg. higher for corresponding zenith distance, than during the summer solstice. By reference to Table B it will be seen that owing to the diminished distance between the sun and the earth, the increment of temperature on January 17, ought to have been 5.75 deg., discrepancy = 0.1 deg. Fahr. In the face of such facts it is idle to contend that the temperature produced by solar radiation under corresponding zenith distance and a *clear sky*, varies from any other cause than the varying distance between the sun and the earth. Of course there are many regions in which the sun, in consequence of local peculiarities, but seldom acts with maximum energy. Alaska, for instance, is hardly ever favored with a full amount of solar heat; nor does Rome, we are now informed by the Italian physicist, receive maximum solar heat excepting during winter, owing, it may be imagined, to the absorptive power of the atmosphere of the Campagna during summer.

Without entering the field of speculation, let us consider that the established diminution of solar heat on the ecliptic, nearly 18 deg. Fahr., proves the existence of a powerful retarding medium, and points to the presence of a permanent mass of aqueous matter in the higher regions of the atmosphere; necessary, it may be urged, to regulate terrestrial temperature and render vegetable life possible under the destructive vicissitudes of heat and cold, inevitable in the absence of a permanent regulator. The assumption that the supposed mass of aqueous matter is nearly invariable, and at all times present, can alone account satisfactorily for the remarkable fact that, whenever a clear sun is presented, either by the opening of the clouds or by their disappearance, the actinometer indicates the same temperature, subject only to the variations depending on the sun's zenith distance, and the varying position of the earth in its orbit. The variation of temperature produced by the latter cause is entered in Table B, for every fifth day in each month. This table, an extract from a more elaborate one showing the temperature for every day in the year, the meteorologist will find indispensable to harmonize observations made at different seasons. It may be mentioned that the attempt to construct a curve, the ordinates of which would determine the temperature for different zenith distances, at first met with apparently insuperable difficulty. The result of observations made at different seasons under the most favorable circumstances, failed to produce a regular curve until the change of temperature corresponding with the varying distance between the sun and the earth was determined and introduced in the calculation. This at once harmonized the previously conflicting observations and rendered the task easy of perfecting the curve, and obtaining ordinates consistent with the observed temperature produced by solar radiation at different seasons and different zenith distances.

Regarding Table A, it will suffice to state that it is based upon our acquired knowledge of the temperature produced by solar radiation at given zenith distances when the earth is in aphelion. Evidently if we know that, for instance, when the sun's zenith distance is 43 deg. the temperature is 60.57 deg.Fahr., we know also that this is the temperature at noon on the Arctic Circle, the latter being 43 deg. from the ecliptic at the summer solstice. Again, the North Pole being 66 deg.30 min. from the ecliptic at the same time, we find by referring to the figures entered in the table of zenith distances and temperatures (previously published) that the depth of atmosphere to be penetrated by the rays when the sun is 66 deg. 30min.from the zenith, is 2.444 times greater than on on the ecliptic; and that, therefore the radiant intensity, as shown in the table, is reduced from 67.20 deg. at the tropic of Cancer to 49.91 deg. Fahr. at the pole.

Possibly it may be found necessary to introduce a correction for the difference of atmospheric density in the higher latitudes; but at present I deem it inexpedient to complicate the matter by applying a correction which obviously cannot affect the general result.

THE INDICATOR AND THE BRAKE DYNAMOMETER.

Translated from "Deutsche Industrie Zeitung."

In the "Mittheilungen des Gewerbevereines für Hanover," 1871, p. 38, Prof. Rühlmann discusses the question, in what relation the mechanical work shown by the indicator of a steam engine stands to the effective work which is transmitted to the axle of the fly-wheel. Of these results, the first is of importance only to the constructor and machinist, while the second is of import to all who would obtain productive manufacturing work from the eng ne. The indicator diagram is not only the machinist's scle means of determining the pressure in the cylinder and the work of the piston, but it also determines whether the dimensions of the steam passages are suitably adjusted, whether the distribution is correct, and also how great is the sum of resistances in friction of piston, piston-rod, etc. All these circumstances are of importance to the purchaser of a steam engine, but he should also know what amount of useful work is communicated to the fly-wheel, for by means of this he changes form or place of a body, thereby earning money. So in the sale of an engine, or the settlement of an important contract of sale, the important question is, what is the amount of useful or effective work? This can generally be found by three methods: The first, by calculation; the second, by means of a brake-dynamometer (Prony's, which is applied directly to the axle); the third, by the indicator-diagram, which gives the indicator horse-power, from which the effective or actual brake power can be derived. The method by calculation supposes certain mathematical formulas, such as those given by Redtenbacher, in his "Resultanten," and by Völckers, in his little volume, "Der Indicator." But these are not entirely satisfactory, since they do not correctly take into account all passive resistances, and since the empirical coefficients heretofore obtained require correction.

Local hindrances are sometimes in the way of direct measurement by brake; such as the want of proper place for its application, the length of time and the labor which are often necessary, and in large engines the possibility of accident, perhaps with loss of life.

The simplest method is the third: that is, to deduce from the horse-power indicated by diagram (N i), the corresponding brake horse-power (N b), by multiplication by coefficients derived from a great number of experiments upon engines of different dimensions. This method generally gives only approximate results; hence it is important to mark out the limits within which performance and demand must lie. Prof. Rühlman considers it sufficient for this purpose to tabulate in chronological order the results of all published experiments with those obtained by himself.

The earliest comparative experiments in determination of effective work were made by the engineers, Jordan and Völckers, in the autumn of 1856, at Clausthal, with a Woolf's beam engine. The small cylinder had a diameter of $9\frac{1}{2}$ in., and the piston a stroke of $1\frac{3}{4}$ ft.; the large cylinder was $15\frac{1}{4}$ in. in diameter, and the stroke was $2\frac{1}{2}$ ft. The results were as follows:

No. of experiments.	Tension in boiler in lbs. to square inch.	Revolutions of fly-wheel per minute.	Nb.	Ni.	$\frac{N}{Ni.}$
1	48.0	36.0	14.56	23.60	0 617
2	43.4	36.87	12.104	15.40	0.786
				Mean	0.710

In 1860, Prof. Rühlman made experiments with a small horizontal engine. The cylinder had a diameter of 10.25 English inches, and the stroke was 21.85 in. The results were as follows:

	Mean tension, Eng. lbs. to sq. in., by indicator.	Velocity of piston, Eng. ft. per sec'd.	Nb.	Ni.	$\frac{Nb.}{Ni.}$	
1	30.31	4.075	13.60	15.91	0.85	Full supply.
2	30.46	3.962	13.86	15.54	0.89	Full supply.
3	35.13	2.717	11.23	12.29	0.91	Full supply.
4	33.63	4.075	14.90	17.65	0.84	Full supply.
5	32.25	3.056	9.50	11.55	0.82	Halfsupply.
				Mean	0.86	

The French engineer, Burel, published the results of an experiment with a large 80-horse-power beam engine (Woolf), in the "Memoires de la Soc. des. Ing. Civ." The indicator diagram showed a work of 93.30 horse-power, and the brake gave a work of 80.312 horse-power; hence.

$$\frac{Nb}{Ni} = \frac{80312}{93300} = 0.86$$

The best managed and most trustworthy of the experiments heretofore made, are probably those of Grosseteste and Hallauer, made with a double cylinder Woolf beam engine, at Mühlhausen. The dimensions were

Small piston	diameter,	0.50	metres.
	stroke,	1.524	"
Large "	diameter,	1.10	"
	stroke,	2.10	"

The number of revolutions varied from 21.333 to 21.494 per minute. The tension in the steam jacket varied from 4.843 to 4.395. Measurements of the water and coal were very carefully made. A Watts indicator was used. The experiments lasted for five days. The results were as follows:

Day of ending work.	Nb.	Ni.	$\frac{Nb.}{Ni.}$
3	189.802	210.047	0.903
4	190.856	212.846	0.896
5	193.668	217.7?9	0.889
		Mean	0.896

A fifth case of comparison of indicator

and brake occurred to Prof. Ruhlman in 1869, when there was a dispute between a maker and a purchaser. The engine had a horizontal cylinder of $13\frac{1}{4}$ (English) in. diameter and a stroke of $34\frac{3}{4}$ in. The experiments resulted as follows:

	Admission.	Mean tension by indicator lbs. to inch	Revolutions per min.	Nb.	Ni.	$\frac{Nb.}{Ni.}$
1	03.41	29.2	56	36.90	49.50	0.745
2	03·60	33.2	55	40.80	55.30	0.738
3	01.55	17.1	57	20.71	29.53	0.702
4	01.57	18.6	55	22.40	31.00	0.723
					Mean	0.727

The sixth case consists of experiments made with a double cylinder locomotive at Hanover. Cylinder of $6\frac{1}{2}$ (English) in. diameter; stroke, 10 in. Results in the following table:

	Revolutions per minute.	Mean tension by ind. lbs. to sq. in.	Nb.	Ni.	$\frac{Nb.}{Ni.}$
1	105	27.70	7.87	9.74	0.808
2	116	30.80	10.35	11.976	0.864
3	120	29.37	9.63	11.81	0.815
4	140	31.60	12.49	14.83	0.842
5	120	34.16	12.42	13.74	0.909
				Mean	0.847

From the above results we may at least conclude that no smaller ratio than 0.70 between brake and indicator is permissible, and that not more than 0.90 is attainable.

GOTHIC AND RENAISSANCE CHURCH RESTORATION.

From "The Builder."

When the history of church and temple architecture comes to be written without thought of anything but the mere facts, and their obvious inferences, what a very curious and somewhat unintelligible history it must be. If the precise mode of conducting ceremonies in the old Parthenon could be come at—and what a pity it is that it cannot—if the defined use of every part of that structure could be discovered, we are quite sure that not a single stone in it would be found to have been put up for nought. Every part of it, both inside and outside, and its decoration, must have had its proper use and significance, and certainly would never have been there at all if it had had none. So of every heathen temple probably in existence from Egypt to India. But nowadays, as the world has grown older and wiser, things are altered; churches and chapels are built, and being built and decorated as well every day, and having parts attached to them for which those who are to make use of them have no need, and who do not know what to do with these strange additions to the bare and actual requirements of the time and circumstances. Some old forms and arrangements have been copied and brought into existence, and made to add, as it is thought, to the architectural and artistic effect of the structure. What was a useful and artistic necessity in the old building, or model, is in the modern copy of it simply an *artistic* necessity. Nothing can possibly be stranger or more worthy of a little thoughtful consideration, and we have been led to it from seeing lately one or two of the City churches now in course of "restoration," as it is called; a chapel now building, with a tall bell-tower attached, but without any bells to fill it, or apparent usefulness or practical purpose, and from the sight—a lamentable one—of the Morning Chapel in St. Paul's Cathedral, now in course of restoration,or whatever other work may be considered best decriptive of what is going on in it, or being done to it. This is modern architecture in practical working, and it would seem to go some way to prove that a really modern architecture, or architectural restoration, does not exist, but only a mode of copying blindly, or following blindly, a something or a somebody gone before us, but passed away. The "restoration" of an old Gothic church would seem to be, to a certain extent, a straightforward sort of work, and to consist simply of undoing all that the last century did in it. Galleries are pulled down; all the closed pews are condemned; the walls and roof are well scraped, and white-wash and yellow-wash got rid of, and the bare wall-surface is made visible; the old pulpit, reading-desk, and clerk's desk come down; the quaint communion-table makes way for a more imposing piece of church furniture; and, in short, by the time all is done, no one going into the building could possibly know it for the same structure; it all looks so new and dainty! This is called "restoration," *i. e.*, the church is restored to what it may be supposed to have looked like four or five centuries ago. What a surprise it would be to modern restorers, if but some old church could be discovered, and exhumed from the dust of centuries, and exposed to modern view, with everything in it just as it was left after some morning "function." What would be done with it, could it be "restored?" and what would become of its furniture, vestments, and books?

But far different is the fate of the Renaissance or Italian City church. For some time, as all know, no one seems to have thought of restoring any of this style of architecture church; they were all left to go on in their own old-fashioned way, so that any man going into a City church went literally and truly into the house of his fathers; nay, the very voices in it seemed of the past, and to come almost from the grave, all looked and sounded so old and dusty. But the spirit of modern improvement and reasonableness has at length entered them, and they are now in active course of what is still called, even when applied to them, "restoration." But this restoration is, strange to say, nearly or quite opposite in character to that adopted in the case of an old Gothic church. Everything is reversed. The walls of the Gothic building are carefully and thoroughly scraped of their coatings of wash, and the bare stone brought to sight; but the walls of the Renaissance church are as carefully and thoroughly coated two and three times with almost solid plaster wash, so thick and heavy and opaque, that the whole surface becomes of one uniform tint, and by no possibility but by breaking away can it be told what the walls are made of, whether of brick, plaster, or solid stone; the very workmen employed to do the work sometimes cannot tell you what the walls are made of. The quaint church of Allhallows the Greater and Less, in Upper Thames street remarkable for its wooden rood-screen, and the "restoration" of which is just completed, exemplifies this; for not only is the whole of the interior of the church coated over in this solid and decorative way, but the whole of the outer porch, and solid stone tower as well, is covered up out of sight with it. It all looks like a bran-new chapel of the very latest possible build. Why should this be, if the stone surface of the Gothic church is a something to have, and to see that we have it, why not the stone-work of this poor Italian building? Stone is stone wherever it is found, and surely it is as good to look at as common colored plaster. But so it is, and it serves to show into what an odd state, things artistic and architectural have fallen. The ceilings, of course, of these churches are similarly treated, and so thickly sometimes is the white-wash put on, that the ornamental details, small mouldings, and small foliage, are almost hidden away altogether by it; all character and modelling is, of course, thus destroyed. It seems, indeed, a thing not a little strange that the work in a Gothic roof should be so carefully cleaned of its wash and coatings of any kind, and the workmanship of it brought to light, while the very same details of ornament, when in a different style, should be as industriously covered over. Professor Cockerell before he commenced the *painting* of St. Paul's, began his work by "yellow washing" in good solid coats the whole of the stonework of the north-east aisle, of course to the almost total destruction of the ornamental details of it, and it was the seeing this deplorable effect of it that probably led him to the yet more fatal expedient of *painting* the rest of the Cathedral —more fatal because harder to scrape off!

We have said that everything is reversed; the Renaissance restorer is the very reverse of the Gothic restorer. Take the wood-work, for instance, the pews, and pulpit, and desk, and communion-table.

In the Gothic church, as all know, it has been the custom to do away with all closed pews, and even a society exists to protest against them, and they have been made to give way to open benches—not always of the most comfortable kind; but in the City church restorations, these pews have been wisely, when the character of the church is taken into account, retained; but instead of all paint and varnish being carefully and industriously cleaned off, wonderful to say, in some instances, the wood-work, though of dark-colored good oak, has been painted and grained in imitation of light-colored oak, and in those instances wherein the real natural wood has been allowed to show itself, the whole of it has been so thickly covered with coats of thick varnish, that it is almost impossible to tell what the wood is, or whether it is wood at all, or only some patented composition, so effectually is the real nature of the natural substance hidden away by the artificial polishing. Wood and workmanship alike go almost out of sight under it.

Has not everything architectural to be yet commenced anew, and is it not a thing for the future to find out the beauty of every natural substance, stone, wood of all kinds, and even metal? Nothing can be more dangerous in the hands of the thoughtless than *varnish*. Like gunpowder and sharp knives, it is a good thing in its way; but give people an unlimited supply of either, and fearful damage must come of it.

In more than one of the City restored churches we could name we will defy anybody to discover the *wood* under the thick coatings of varnish with which it is covered. But, why varnish good dark oak-wood at all? Is it not better to let the natural material show itself? And if there be any practising architect who asks for a way to add to the plain natural beauty of the newly-wrought wood, we can point with confidence to a common briar-root pipe as an example of it. A little oil and elbow-grease only are needful to bring out all the markings and color of the finest or the very plainest of natural woods. Does it not seem a pity that the great problem of architectural and artistic restoration should not be better understood, and that before any more churches are restored, or before St. Paul's Cathedral, which is destined to go through this process, is finally given over to the experimentalists, some public art-body, as the Institute, should not report and perhaps advise upon the modern system.

We must not, even in this slight notice of Renaissance restoration, omit to notice what would seem to be a sort of generally-received restorer's axiom, for we see it everywhere—we allude to the system of painting—where all else is left bare—the architrave, and cornice, and jambs of stone doorways. We speak of this more especially because of the recent painting in this way of the finely-designed small doorway in the north-east aisle of St. Paul's. Why so treated, it being out of the way of visitors and sightseers, it would be hard to say, or what motive there could be in singling it out for painting, and thus throwing it out of the Cathedral harmony. Another fine doorway in St. Paul's treated in this poor way is the doorway in the south transept leading into the vaults or crypt, a singularly unfortunate spot to pitch on for such bright and new-looking work; for no one expects a crypt filled with coffins and dead men's bones, to look new and smart. Such a place must be dismal, and look old and time-worn, and one would have thought that the doorway into it from the body of the church might have been led to harmonize with it, and allowed to remain as it was, and to look old and quiet, if but by way of prelude to the solemn place it led to. But we live in practical and business-like times, and cannot be expected to see poems in architecture!

THE RIVERS OF FRANCE.

From "Engineering."

M. Thomé de Gamond, the French engineer, so well known for the numerous grand projects he has from time to time made public, and whose name has long been connected with the Channel Tunnel scheme, has recently published a treatise upon the running waters of France, which evidence a great amount of labor, followed with perserverance during a long series of years. Even in 1832 M. de Gamond proposed to the French Government a comprehensive plan for the utilization of the interior waters of the country. But at that time the spirit of co-operation for the execution of great works of public interest was not developed as it was 15 years later for the construction of railways; the carrying out then of a reform in the régime of the rivers fell entirely on the State. But in spite of the good-will of various people in authority, whom the author had succeeded in convincing, the Minister of Finance, although much taken by the fruitful promises of the project, placed a veto upon its adoption, on account of imperative economical reasons. M. Thomé de Gamond was then obliged to renounce the realization of his plans, but he nevertheless continued to study them out in all their details.

In 1843 a certain public movement towards the pursuit of great enterprises induced the author to present anew his work to the Government. But it was objected that the great project would be entirely obnoxious to the railway interests.

The same under the Republic of 1848, and under the Empire: the Ministers of Public Works successively examined the question, and unanimously praised the perseverance and industry of the engineer, but they all urged the impossibility of carrying out so great a work before the *réseau* of railways was completed.

In 1862 M. Thomé de Gamond brought his project before the public in a series of 10 articles published in "La Patrie" under the title of "The Rivers of France." The engineers, charged with the various hydraulic services of the departments, for the most part approved the simplicity of the proposed plan. This reform appeared to them the more acceptable because it was the practical generalization of methods proved separately and by experience. But the approbation of the engineer was not sufficient to insure the execution of the project, and to-day the author comes forward again to submit it to the consideration of all those who have the prosperity of France at heart, hoping that in the presence of such promising results the spirit of co-operation so fully developed in his creation of railways, will not be wanting for his scheme.

What this scheme is, we may gather from M. Thomé de Gamond's essay upon the required reform in the general régime of the inland waters.

Instability is the principal inconvenience in the actual condition of things. The waters flow in the upper effluents down steep slopes into the great collecting rivers, which generally present but a slight fall. It results from this condition, that the feeding streams situated far up streams empty themselves rapidly, by reason of their velocity in times of flood, whilst the waters accumulated lower down spread themselves over the land, causing frequent inundations. The harvests in the upper plains are then made barren through dryness, whilst the lower valleys of the rivers are flooded. This disordered state of things arises solely from the natural irregularity in the profile of the inclined plane along which the flow of the waters takes place towards the ocean.

The works already undertaken to improve the natural régime, are sufficient to prove the immense resources that could be developed. There are plenty of examples to show the benefits that are to be obtained by the utilization of the rivers, and no inventions are required to put into use these treasures of force and fertilization. It is enough to appreciate and to imitate the results already obtained, in generalizing upon a comprehensive plan applicable to the entire country, the practice undertaken at home and abroad.

M. Thomé de Gamond proposes to suppress the natural profile of the large watercourses which are imperfect, and to substitute for them a series of regular planes in successive slopes. This would be, in other terms, the transformation of the inclined planes of rivers into hydraulic staircases. The full régime would be maintained in those rivers where, in the natural state of things, the water is sometimes deficient, and sometimes in excess. For this purpose the overflow would be regulated by dams for the retention and distribution of the water, and there would descend to the sea only that portion which would be in excess after it had fulfilled all the numerous useful purposes for which it would be destined. Spacious reservoirs would also be established at the higher levels for storing up a portion of the superabundant rain water, to utilize it during dry seasons. These reservoirs would form lakes some miles in length, and of variable width, enclosed in valleys, and containing water 60, 80, or 100 ft. deep.

The rivers of France, from their source to the sea, would be divided into a multitude of reaches, maintained by weirs, a system well known upon many canalized streams. The régime of outfall being thus distributed among basins at constant levels, it would be easy to regulate the different hydraulic systems according to the available supply, the irrigation of land, the motive power in the various falls, the navigation, etc. The necessary precautions against inundations would be much simplified, and would be reduced to measures partly administrative. Extreme velocities would be suppressed in the river beds, where the slopes were heavy, to be localized carefully in the various weirs, when they would produce immense hydraulic power now lost, to the benefit of every kind of industry. The current being almost entirely on the surface of the water, the disintegration of the banks, and the encumbering of the beds of rivers, would be avoided. At the higher levels floods would be unknown, and the denudation of the ground, so fatal to agricultural property, would cease.

M. Thomé de Gamond gives a general Table of the various rivers in France, classified by their natural basins. Abstracted, this Table is as follows :

Name of Basin.	Area in square miles.	Population in thousands of inhabitants.	Total length of the river in miles.	Mean slope in parts per 1000.	Mean volume of diurnal rainfall in millions of cubic feet.	Mean volume of diurnal discharge into the sea in millions of cubic feet.
Seine	28,605	6,867	9,139	0.95	1,645,615	761,799
Loire	42,604	6,853	20,059	1.23	2,688,130	1,096,170
Gironde	33,503	5,082	17,469	2.86	2,621,060	1,311,359
Rhone	36,506	6,327	10,918	2 28	3,308,774	1,914,530
Rhine	14,183	2,969	5,632	1 03	974,280	269,692
Escant	1,202	1,044	715	0.53	71,094	106,651
Manche	16,705	4,499	5,094	2 00	1,345,671	293,907
Ocean	18,287	3,181	8,930	0 92	1,430,426	386,676
Mediterranean	10,836	1,462	3,737	3.15	637,906	208,164
Totals	202,431	38,284	81,693	1.52	14,722,956	6,348,958

The total volume discharged into the sea is about 180 milliards of cube metres, corresponding at the rate of 140,000 cube ft. to the acre, to the irrigation of 45,000,000 acres, if the whole of this volume was employed in irrigation. This same volume could furnish by its fall the enormous amount of 12,000,000 of horse power. Both these questions of irrigation and power are studied by M. Thomé de Gamond. He shows that France lacks meadow lands, that she could lay out immense areas to receive irrigation, that by increasing the number of cattle raised more manure would be available for the cultivation of cereals. He calculates that a rent of 16 francs per acre per annum could be obtained for irrigation.

The chapter on motive power shows that there exist in France about 40,000 dams, and that there would be established an equal number of new dams, having an average fall of 10 ft., each able to furnish, after deducting the due proportion for irrigation, a mean force of 40-horse power. Industrial establishments could thus spread themselves over the whole surface of the country under the most favorable conditions, the use of steam would be reduced to very narrow limits, and the exhaustion of coal supplies would become a question for the remotest consideration. It is proposed by the author to fix the rent of each horse power at 72 francs per annum.

Considering, then, the condition of the

present régime, and passing on to review the various means suggested to improve it, M. Thomé de Gamond proposes to raise the level of the outfall of oceanic rivers, very sensibly, 2 ft. for example, by means of a dam interposed transversely across the embouchure of the river. These dams would be monolithic, raised above the beach, and intended to hold back the sea within the limits of its own domain. The sea, spreading out at the foot of these structures, would deposit shingle and sand along its whole length. The volume of water in the river reduced by that amount taken for irrigation, and regulated by the high-level reservoirs, would discharge itself over the crest of the dam, and at low water by sluices.

The access to the great seaports of France would then be improved for ships of heavy tonnage, and the great river harbors would be opened for navigation by transforming the sea channels into vast lakes of fresh water, independent of the sea. The ebb and flow of the tide would be suppressed. An outer port accessible in all winds would receive the ship between two jetties running obliquely from the shore, and they would communicate by locks with the upper level of fresh water. The internal navigation would be found also greatly improved, all the reaches being always kept full of water from their sources to the sea. Great lines of water communication could also be completed, and thus an important auxiliary to the railways would be formed. The maximum level being assured in all the reaches by the construction of the proposed dams, it would only remain to connect the former by locks. It would be necessary to have about 4,000 locks to open a navigable system of more than 18,000 miles, to which would be added the 2,500 miles of imperfect canals France to-day possesses. At the rate of 80,000 francs for each lock, the cost would amount to several hundreds of millions.

Fish culture could be introduced on a grand scale in the improved rivers, and from this source alone, according to the author, an enormous revenue would be derived. It is urged that inundations could be successfully prevented were the proposed measures carried out, thanks to a system of regular discharge, and to the means taken for the storing up of the rain water in the upper valleys.

Up to the present time the various problems which we have thus passed under review have only been worked out independently. Thus there have been executed the necessary works for the utilization of rivers for the supply of cities, for obtaining motive power, for irrigation, and for navigation, whilst in isolated cases the means for defence against inundation have been carefully studied. But nothing approaching a general and comprehensive scheme has ever been developed, and the rivers lose themselves in the sea without being utilized. It is urged that the absence of the spirit of co-operation has hitherto prevented this reform, and it is proposed that in each of the basins named above, a powerful company should be formed analogous to that of the railway companies. These companies would have no cause for demanding State subsidies, because the enterprise would become highly profitable. They would have each the development of the various water services under the control of the State; they would have to pay to Government annually one-tenth part of their receipts ; they would possess entire control of the management ; and at the end of a concession of a century's duration the whole of the works would revert to the State.

The whole of the expense for 40,000 dams, 4,000 river locks, and 262 marine locks, the acquisition of lands, the construction of irrigating canals and conduits, the buildings, machinery, earthworks, etc., would of course be enormous. The annual receipts derived from irrigation, power of navigation, fish culture, etc., are assumed to amount to 550,000,000 of francs, a sum which would largely repay for the capital invested. Such is the magnificent scheme which M. Thomé de Gamond has once more brought forward. It is a scheme at which he has carefully labored until he has developed its closest details, and the advantageous results anticipated are possibly not overdrawn. But it is to be feared that, even while comprehending the grand development of prosperity that even the partial execution of this project would bring about, public opinion will remain almost indifferent to propositions. And at present, France, having the utmost need of energy in pushing forward in the path of progress, is yet paralyzed in her efforts by the rigid exigencies of necessity.

REPORTS OF ENGINEERS' SOCIETIES.

INSTITUTION OF MECHANICAL ENGINEERS.—The general meeting of the members of this Institution was held at Birmingham.

The first paper read was a "Description of Miller's Cast-Iron Steam Boiler," by Mr. John Laybourne, of Newport, Monmouthshire. This boiler is composed of a series of cast-iron sections, of 2 patterns only, each of comparatively small size, so as to contain only a small quantity of water; those at the front end form a succession of arched tubes over the fire-grate; and the rear sections consist each of 5 vertical tubes, united by a transverse horizontal tube at top and bottom, and placed with the tubes in each section opposite the spaces in the next. The whole of the sections of both patterns are bolted together by flanged joints at the bottom, each section having a communication through the bottom joints with the adjoining sections on either side; and a smaller wrought-iron p pe from the top of each section conveys the steam to a main steam pipe common to the whole boiler. All the joints are protected from the action of the fire, those at the bottom being below the fire level, while the joints at the top are in a chamber above the top of the flue. For the purpose of insuring efficient circulation of the water in all portions of the boiler, the arched sections at the fire end are cast with a longitudinal mid-feather in each leg, by which the ascending current of heated water on the inner side exposed to the fire is separated from the descending current of cooler water on the outer side; and in the rear sections the vertical tubes have an internal circulating tube placed within each, the heated water ascending through the outer annular space, and the cooler water descending within the circulating tube. All the sections of the boiler are left free to expand with the heat, the rear sections being attached together by only a single central joint, and the wrought-iron steam pipes at the top are long enough to allow of yielding to the requisite extent; the arched fire-box sections are attached to the rest of the boiler on one side only, and are free to expand on the other side. No case has occurred of explosion with any of these boilers; and in the very few instances in which accidental fracture of the cast iron has taken place, the only result has been that the water contained in the boiler has flowed out through the crack, without causing any damage beyond putting the fire out. By means of the flanged joints a broken section in any part of the boiler can be readily removed, and replaced by a new one, without disturbing the rest of the sections, which are all duplicates of one another. Specimens were exhibited of fractured pieces taken from the boilers, illustrating the harmless nature of the cracks occurring in the cast iron, and showing also that the quality of the metal remained unimpaired after more than 2 years' working. The boilers are kept clean by blowing off at regular intervals, according to the quality of the feed-water, and any deposit accumulating in the bottom portions is raked out, whenever necessary, by taking off the bottom covers at the ends of the boiler. As the total quantity of water contained in the boiler is small, in proportion to the extent of heating surface, the water level is in some cases maintained at the required height by means of a self-acting feed apparatus, consisting of a hollow ball suspended from the arm of a lever controlling the feed cock; two pipes extending some distance horizontally communicate respectively with the top and bottom of the ball, the former terminating at the high-water level inside the boiler, and the latter at a lower level. As soon as the water level rises and covers the orifice of the upper pipe the steam previously contained in the ball becomes condensed, and a vacuum is formed; and the ball then becoming filled with water entering from the boiler, depresses the lever, and shuts off the feed. When the water level falls again below the orifice of the upper pipe the water runs back out of the ball into the boiler, and a counterpoise upon the lever raises the ball and turns the feed on again. One of these cast-iron boilers has now been at work for $2\frac{1}{2}$ years at the writer's works with complete success, and with an important economy in fuel. Several other boilers of the same construction are also in use at other works, and have proved entirely satisfactory. The particulars were given of a series of experiments made to test the evaporative power and economy of the boiler at the writer's works; and the average duty amounted to nearly 11 lbs. of water evaporated from 100 deg. temperature of feed per pound of Ebbw Vale coal.

The next paper was "On Steam Pressure Gauges," by Mr. Ernest Spon, of London, communicated through Mr. Charles Cochrane. The reliable construction of steam pressure gauges is of much importance in connection with the safe working of steam boilers, a great number of the spring pressure gauges in ordinary use having been found inaccurate, either from defects in original construction or in consequence of their becoming unreliable when in constant use. In the Bourdon gauge, which is the spring pressure gauge that has been the most extensively used for a great number of years, the indication of the pressure is obtained by the employment of an elastic metallic tube, bent to a curved form, which when subjected to internal pressure becomes less curved; and the resulting movement of the free end of the tube communicates motion to an index upon a dial, through the intervention of a lever or a toothed sector and pinion. The elastic tube, however, is liable to become permanently strained by continued use, or by accidental exposure to an excess of pressure; and the indications of the gauge are then no longer correct. In the Schaeffer gauge the pressure is measured by the deflection of a circular corrugated steel plate, fixed round the circumference and bulged in the centre by the pressure, the extent of the bulging being magnified upon a dial by means of a toothed sector and pinion. This gauge, though it has been considered one of the best in use, has a disadvantage in the very small range of deflection of the plate under the pressure, requiring the motion to be very largely magnified upon the dial, whereby any errors are also proportionately magnified. The plate is also liable to be permanently strained by an excess of pressure, and is moreover liable to crack when continually worked. The metal of this plate being very thin, as is also the case with the elastic tube of the previous gauge, its elasticity is liable to be diminished when any oxidation takes place, and error in the indications is then the consequence. The pressure is also measured by the bulging of a circular steel plate in Wallis' gauge but the deflection is increased by the plate being cut into five segments by radial slits; and a thin brass diaphragm or a sheet of vulcanized india-rubber is used to cover the slits on the side exposed to the pressure. The brass diaphragm, however, is found too rigid to admit of the requisite sensitiveness in the gauge; while the india-rubber is liable to get forced into the slits by the pressure, thereby obstructing the action of the gauge. A solid piston working in a cylinder is supported against the steam pressure by a steel spring in Miller's gauge, and is rendered steam-tight in the cylinder by an india-rubber diaphragm, which is fixed round the circumference between the flanges of the cylinder; the motion of the piston is communicated to the index by means of a short chain, coiled round the spindle of the index, and attached to the arms of a vibrating bow, which is actuated by the piston rod. The motion of the piston is limited to a very short range, owing to the risk of the india-rubber diaphragm getting cut round the edge of the piston with a longer action; and the construction of the multiplying gear for the index involves objectionable complication. In Smith's gauge, which has been extensively used, a steel volute spring is employed, and is acted upon direct by the steam on one side, being covered on that side by an india-rubber diaphragm secured round the circumference to make a steam-tight joint. This spring has a considerable range of action compared with the gauges previously noticed, and being of considerable substance is not liable to be affected in strength by corrosion; the deflection of the spring moves the index by means of a rack and pinion. Three concentric spiral springs, placed one within another with their ends covered by an india-rubber diaphragm, are employed in Silvester's gauge, which is similar in principle to the last one; and the motion is communicated to the index by a rack and pinion. There is, however, an objection to the employment of a rack and pinion for actuating the index of a pressure gauge, on account of the play occurring in toothed gearing; and in Foster's gauge, in which the pressure is measured by the deflection of a volute spring covered by an india-rubber diaphragm as before, the movement of the spring is transferred direct to the index, by means of a stud fixed to the centre of the spring and working in a spiral groove in the spindle of the index. This pressure gauge has been found by the writer to be superior to the other gauges in use, in regard to durability, accuracy, and sensitiveness. The strength of spring employed is proportionate to the limit of pressure to be measured, the total range of deflection being the same in each case. Specimens were exhibited of the various gauges described, and the action of some of them was shown by means of a force pump.

An adjourned discussion followed upon a paper read at a previous meeting, "On the Principal Constructions of Breech-Loading Mechanism for Small-arms, and their Relative Mechanical Advantages." The special features of the Henry and the Soper rifle were pointed out by their respective inventors; and specimens were exhibited of these and numerous other breech-loading rifles in illustration of the descriptions given in the paper. It was remarked that the particular construction of breech mechanism in the Martini rifle, which had at present been selected for the national weapon, was open to serious objection from a mechanical point of view, more especially in the substitution of a spiral main-spring with direct action and short range, in place of the ordinary flat main-spring acting with a variable leverage, the latter having been proved by long practical experience to be completely successful for the purpose. By the use of the spiral spring, the pressure upon the trigger nose at full cock is so greatly increased as to necessitate the addition of an exceptionally delicate contrivance for facilitating the pull-off in firing, and a consequent liability to irregularity in resistance is entailed; but the whole of this objectionable complication is obviated by reverting to the ordinary flat main-spring, and an easy and uniform pull of the trigger is obtained.—*Engineer.*

American Institute of Mining Engineers.—The third and a very successful meeting of the Institute of Mining Engineers has just been held at Troy, N. Y. The members were hospitably received by the citizens, and an address of welcome was given by the Mayor. The principal iron works and furnaces in that vicinity, and at Albany, were thrown open to the inspection of the members; and upon the invitation of the Port Henry Iron Company, they visited the celebrated iron mines at Moriah, in Essex County. The Bessemer steel works of the Messrs. Griswold, the new anthracite-burning iron furnaces below Albany, and the extensive furnaces and rolling mills of the Messrs. Burden were visited in succession.

The sessions for the transaction of business, and the reading of papers, were held in the evenings in the Common Council Chamber, and were well attended by the members and others specially interested in the manufacture of iron and of steel. Most of the communications related to these industries, but there was one very valuable paper by Mr. Eilers (the assistant of Commissioner Raymond in the collection of mineral statistics), upon the Metallurgy of Lead and Silver in Utah and Nevada. Among other papers were the following: Manufacture of Bessemer steel, by Prof. Drowne; Late Improvements in Blast Furnaces, by Prof. Egleston; Iron Manufacture in the Lehigh Valley, by David Thomas, the President of the Institute; Electricity and Mineral Veins, by Prof. Raymond; Efforts to make Iron in Blast Furnaces in Japan, by Prof. Blake; Iron Deposits of Essex County, by Prof. Maynard; Description of Krupp's Steel Works, by Prof. Egleston.

Some or all of these papers will be published in a volume at the end of the year, and will be distributed to the members.

Engineering Society, King's College, London.—At a general meeting of this Society, held on Friday, October 27th, Mr. Hunter, president, in the chair, Mr. Gamble read a short paper on the manufacture of carbonate of soda, describing the manufacture of sulphuric acid, and its use in the preparation of salt cake, or sulphate of soda, from common salt, and the conversion of the sulphate into carbonate. He concluded by enumerating the chief processes lately invented for the improvement of the manufacture.—*Engineer.*

Edinburgh and Leith Engineers' Society.—At the last ordinary meeting of this Society, a paper was read by Mr. Alex. B. W. Kennedy, consulting engineer, on "Marine Propulsion." The paper was divided into two distinct sections: (A) The cause of the resistance to be overcome by a vessel. (B) The methods adopted in practice for proportioning the power to the resistance. Each of these divisions was taken up at considerable length, and treated of in an able manner. Under the first heading, in showing the various resistances—direct and indirect—opposed to a vessel's motion through the water, the author dwelt much on the theory of wave-lines. He showed that every ship must be accompanied in its progress by a wave-crest both at bow and stern, and by a wave-trough amidships. These waves, if once started, would continue of the same size for thousands of miles, and in the case of a ship rightly proportioned would cause no loss of power to produce or overcome them so long as their path of direction remained parallel to that of the vessel. In well-designed vessels no other waves were created. The main hindrance to a vessel's progress the author showed to be "eddy resistance." Eddies were produced by the skin of the ship coming in contact with the particles of water next it. The energy absorbed in producing these eddies constituting the real source of resistance in full-sized vessels, Rankine and Wiesbach had deduced formulæ from which the eddy resistance could be calculated with tolerable facility. In the second part of his paper the author laid down the various methods usually adopted for ascertaining the horse-power of engine required to overcome the eddy resistance of any vessel of about the average degree of sharpness of stem and length of stern. The Admiralty formulæ generally used for this purpose he showed to have many disadvantages, as they required the amount of displacement to be known, which was very often difficult to ascertain, while the coefficient which they introduced varied much with vessels of different size and construction. On the other hand, the formula by Professor Galmyden was much more reliable, as introducing a coefficient which was nearly constant for differently built vessels. The author himself had spent much time in making calculations whereby he succeeded in rendering Galmyden's coefficient more nearly constant by taking into account the mean entering angle of the vessel. The author then spoke of the superiority of compound over ordinary engines, while a large number of carefully executed indicator and other diagrams appealed to the eye as to the truth of the results which the writer obtained by calculation, based chiefly on a coefficient of steam efficiency deduced by himself. A paper was also read by Mr. Alexander M. Mackay, the Secretary of the Society. The object of the paper was to expose the present comparatively imperfect state of knowledge on the subject of the resistance to vessels in water, and their consequent most approved forms of construction. Allusion was made to numbers of experiments on frictional resistance; their results were summarized, and some practical conclusions drawn therefrom.

IRON AND STEEL NOTES.

Iron Manufacture in France.—Serious attention is now directed in France to the establishment of new works in that part of the Department of the Meurthe which remains to the country, as well as to the great extension of various existing works. We have already noticed the exceptionally favorable opportunities which the peculiar conditions of France now offer to the various iron industries. Although so large a proportion of the mineral districts has been ceded to Germany, there remains, as we have shown, abundance of ore, easily extracted and worked, with coal and coke at low prices from the Department du Nord, and the Prussian basins, together with an ample supply of labor on favorable conditions, and every facility of transport by railway and canal. It is true that easy terms of import have been accorded to the annexed departments for the benefit of their industries, but these arrangements are exceptional and temporary; the annexation will of necessity have the effect of taking away 150,000 tons of iron annually from France, whilst the demand in the country increases each year by about 50,000 tons.

It is, moreover, evident that there will be with reviving industry, a large field for the sale of cast and wrought iron, and that there will be room for highly remunerative enterprise in the mineral districts. That the project we have spoken of will find ample favor, there is every reason to believe; and we have no doubt that English capital will flow into these chanels of assuredly profitable investment.

The following telegram was received from the Commissoners sent out to America to report on Danks' puddling machine:

"Danks' furnace successful. Construct furnaces for ten hundredweight; squeeze or hammer single ball. Economy and quality satisfactory. Commission well."

The announcement we make above to the effect that the Commissioners sent out by the Iron and Steel Institute to investigate the merits of Danks' Rotatory Puddling Furnace have found the machine successful, will create no small amount of interest among British ironmakers. We apprehend that the brief telegram, received in this country a few days ago, would not be forwarded by the Commissioners until they had not only satisfied themselves that the machines were in successful operation in America with the materials available there, but that the English materials could also be used in machines without difficulty. We anxiously shall await the detailed report which the Commissioners may be expected to bring with them in the course of a few weeks, as this will, doubtless, set forth under each head of the inquiry, suggested by the Puddling Committee, all the facts connected with the working of the machine puddler. The telegram, however, is highly suggestive, and opens up a prospective revolution in the finished iron trade. Danks himself spoke of furnaces manipulating from 600 lbs. to 800 lbs. of iron. The Commission advise the construction of furnaces to puddle over 1,100 lbs. of iron, and assert that this large mass can be hammered or squeezed into a single ball. This seems to indicate that the iron is brought out of the machine in a much more homogeneous and purer state than from the ordinary puddling furnace. It will be readily seen, that in addition to the machine puddlers, the appliances for hammering and rolling the large puddled blooms will have to be on a far larger scale than those at present in use. Hence, those who take up the revolving puddling furnaces must be prepared to reconstruct their forges entirely. The Commissioners add that economy and quality are satisfactory. This we take it to mean that the consumption of fuel, yield of iron, and labor required in working the machines, produce, combined, a marked economy when contrasted with the existing methods; also, that the iron produced is in quality satisfactory. If we may assume from the telegram that the machines have been found successful in manipulating English pig iron, when fettled with the materials available in this country, and that the results have been satisfactory to the Commissioners, we may reasonably conclude that the question of machine puddling is virtually settled. When the detailed report comes to hand, it will doubtless contain many suggestions which those who adopt the furnace in this country will do well to consider ; hence, we do not suppose that the information now received will be thought sufficient for any one to proceed upon. As far as we can gather, there are several details in connection with the machine and with the squeezer of Mr. Danks, that may be improved by English engineers, and that would be so improved by Americans as they become better acquainted with the machinery. In the course of a short time the patentee himself will be back in this country, when he will be able to advise on all matters connected with his system. The sum fixed by Mr. Danks as royalty for the use of his machine seems moderate enough—2s. per ton. We expect to find that he will not have altogether plain sailing in maintaining his patent rights. The rotatory principle of the machine is not new; but we understand that there are several points upon which the validity of the patent rests, so that Mr. Danks asserts that he is safe. The fact that a considerable number of machines are working in America, and are paying royalty, would seem to indicate that the patent is good ; or its weakness would have been discovered before this in America, as nearly every invention of importance connected with the iron manufacture is protected in America, as well as in this country; and Mr. Danks must have fallen foul of some of these before this, if his position had not been well founded. This, however, is a matter for the patentee to put right. The sums involved, even at a low royalty, are so large that manufacturers and patentee may be expected to look very keenly after their respective interests. The Iron and Steel Institute has done good service to the iron trade by the energetic action it has taken in this matter, and has by this means given a further proof of its usefulness to the trade generally.—*Iron and Coal Trades Review.*

Iron Trade of Great Britain.—The total amount of pig iron exported from Great Britain to all countries during the first 10 months of the present year amounted to 900,911 tons against 641,678 tons during the corresponding period of the previous year. Of this quantity the United States took this year 156,757 tons against 97,586 tons last year, an increase of 59,171 tons or 60 per cent. During the month of October we imported 24,696 tons, about double the quantity imported in October 1870. Of bar, angle, bolt and rod iron, which in the Board of Trade returns are not separated, the importations in the 10 months above designated reached 51,967 tons against 38,354 tons in the previous year, an increase of 13,613 tons, or 35 per cent. In the month of October we imported 4,522 tons, a slight falling off as compared with the same month last year. The exportations of these classes of iron from Great Britain to all countries amounted to 293,021 tons. Of railroad iron, Great Britain exported 846,6(6 tons of which 441,7(9 tons were shipped hither. We thus see that the United States is a better customer for British rails than all other countries combined. In fact the exportations to other countries generally show a falling off as compared with last year's figures. Russia, for instance, took but 75,028 tons this year against 204,005 last year. The shipments to Germany, Holland, Spain, Austria, Chili, India, all show a marked falling off. The shipments to the United States during the month of October, reached the enormous aggregate of 82,174 tons, exceeding the whole quantity made in this country in that month. Of hoops, sheet, boiler and armor plates, we imported 35,553 tons against 34,430 tons last year, a slight increase. Of old iron for re-manufacture Great Britain exported 119,899 tons, and although the countries to which this was sent are not enumerated in the returns, we presume that at least 90,000 tons were shipped to the United States. Of steel, not including Bessemer steel rails, we imported in the 10 months 16,863 tons, against 13,910 tons last year. More than half of the steel shipped from Great Britain is sent to this country. We commend the above facts to our members of Congress, and hope in consideration thereof, they will be slow to adopt a policy that will compel us to obtain from abroad all of the iron required by our busy people.—*Bulletin of Iron and Steel Association.*

RAILWAY NOTES.

Railways in Australia.—The consumption of railway iron in Australia and New Zealand has not made any very great progress of late, having amounted to August 31 this year to 11,382 tons, as compared with 6,023 tons in the corresponding period of 1870, and 15,827 tons in the corresponding period of 1869. Possibly the falling off observable, as compared with 1869, may be recovered before the end of the year, but still rails and railways do not appear to have made any very great advance in Australia and New Zealand. The aspect of affairs is, however, now of a more promising character than at any former period, and a considerable length of railway will probably be constructed in the course of the next decade. It is easy to see why more has not been done in the past. The railway system is still not 50 years old, and it is little more than 30 years since it became a power in modern society. It is only 20 years, again, since our railway contractors, engineers, and capitalists began to push afield, and the principal colonies which have engaged their attention have thus far been Canada and India. Now, however, that Australia and New Zealand have accumulated between them a white population of about 1,800,000, and now that the foundations of young empires have been laid at the Antipodes, we may expect to witness a more tangible advance in the matter of railway construction. At the same time we must not lose sight of the fact that the industries which have thus far been developed in Australia are, to a great extent, of an agricultural and pastoral character. Agricultural industry, of course, stands in comparatively little need of railway communication. Moreover, although the

Australias now boast a white population of 1,800,000, it is scattered over an enormous area, and distributed over 7 colonies, some of them divided by great seas from Australia proper—New South Wales, Tasmania, Western Australia, Victoria, South Australia, New Zealand, and Queensland. This scattering of a still sparse population is, of course, a great drawback to the development of Antipodean railways.

Nevertheless, there is more stir just now in the Australias about railways than at any former time in their history. Thus a bill has been brought into the Parliament of South Australia for the construction of a line between Adelaide and Glenelg. The traffic on the existing lines of South Australia has sensibly improved this year as compared with 1870, which was a period of depression for the colony. Preliminary measures have been taken for the construction of a railway between Waitaki and Moeraki, in the province of Otago, New Zealand, and the general government of that colony has consented to carry the Clutha Railway somewhat further. The construction of a tunnel upon the Duneden and Port Chalmers line, at a point termed the "saddle," has been proceeded with of late day and night. Operations on the line, which is of no great length, are also being pushed on generally with much vigor, the necessary capital having been lately raised in England by debentures negotiated through the medium of the New Zealand Loan and Mercantile Agency Company (Limited). In Victoria there has especially been a large measure of railway activity—a matter not to be wondered at when we find that mechanical industry has now attained such a stage of development in the colony that the Colonial Government has just been enabled to accept a tender delivered by a Ballarat firm for 10 locomotives at £2,900 each. In New South Wales, the permanent way of the western line has now been laid to a point 101 miles from Sydney, and only 11 miles remain to be laid to complete the Northern line to Murrurunde. In Tasmania a contract for the construction of a main line railway from Lauceston to Hobarton has been signed by the Governor, Mr. Du Cane, and has been witnessed by the whole of his ministers; so that the project, which is obviously fraught with important consequences to the colony, may now be expected to proceed to its ultimate stage of development. The capital for the line will, probably, be found by a British company on the faith of a guarantee of interest given by the colony. In the province of Auckland, New Zealand, the construction of a line, which is to connect the head waters of the Waitemata on the east coast with the vast inland sea of Kaipara on the west, has at length been commenced. In the province of Nelson, New Zealand, surveys for a railway from Nelson to Fox Hill have been made, and the plans are now in Wellington. As part of a through line to Westport and Greymouth, such a work would be of the highest possible advantage to the province, and, indeed, to the whole colony. All these details, taken together, tend to the conclusion that the demand for railway iron, although sluggish at present, will increase in the Australias.

Working Railway Inclines.—Description of Brake Drums and the Mode of Working them at the Ingleby Incline on the Rosedale Branch of the North Eastern Railway. Abstract of a Paper read before the Institution of Mechanical Engineers at Middlesbrough, by Mr. John Haswell.—The Ingleby Incline is used for the conveyance of ironstone from the mines near Rosedale Abbey, being a portion of the line. It is nearly a mile in length, with a gradient of 1 in 5¾, the steepest being 1 in 5. Loaded trains descend the incline, drawing up at the same time the empty trains, a passing place for the two trains being made in the middle of the length of the incline, by a short double line, and the rest is only laid with three rails, the centre one being common to both up and down trains. The incline is worked in the usual manner of steep mineral inclines by means of a pair of brake drums keyed upon a horizontal shaft, and situated at the top of the incline. The descending train of loaded wagons pulls off the rope from one of the drums, and winds up that on the other, thereby drawing the return train of empty wagons up the incline. Speed is controlled by powerful brakes upon the drums, controlled by a hand winch. The peculiarity of the brakes is the use of cast iron. The drum barrels are 48 ft. diameter, and 4 ft. 8 in. long, made of cast iron 1½ in. thick, and put together in four segments, which are bolted together. Chipping pieces are cast into the face of the flanges, and the segments are fitted so as to form the circumference of the winding barrel with complete accuracy. The wrought-iron brake straps extend round each side of the drum. They are lined with cast-iron brake blocks, and are bored out to fit the corresponding turned blocks on the rim of the drum. The two brake drums weigh together 68 tons, and the shaft carriages and brake segments about 26 tons. The ropes are made of steel wire, each 1,650 yards long, and 5 in in. circumference, weighing 8 tons. The rope end is taken through a hole in the side of the drum barrel, and wound two or three times round the shaft, and secured by a loop knot. A tail chain 12 yards long is attached to the other end, with riding chain 2 ft. long for the purpose of disconnecting the rope and tail chain when the rope is tight. At the top of the incline are a series of pairs of inclined lateral chocks, fixed at intervals between the centre of the rails of the loaded wagon line; these chocks are pressed outward against the wheels of the wagons, to check the speed of the loaded wagons until the drum rope is attached to them. The average loaded train weighs 52 tons, and the unload does not exceed 25 tons. Each run on the incline occupied three minutes, so that the speed of the train is 20 miles an hour. In ordinary working, 200 wagons are run down per day of 12 hours, carrying 1,600 tons of ironstone. These brake drums have now been at work about 10 months, and superseded 2 smaller drums of 14 ft. diameter, which had been working about 10 years. The smaller drums were fitted with brakes of wrought iron and elm wood. These required renewal every 5 weeks, at a cost of £20, and thus a saving of £200 per annum is effected by introduction of the cast-iron surface to the drum and brake.—*Am. Railway Times.*

ENGINEERING STRUCTURES.

Progress of the Artesian Well in Boston.—The work of boring the well was begun in the latter part of the month of March last, and has been going steadily forward up to the present time, the progress made being from 1 to 15 ft. each day, at a cost of $15 per foot, and as the well has already reached the depth of 1,000 ft., of course the cost already foots up $15,000, and how much more it will take is a matter of uncertainty; but even should it cost $30,000, the company would save the amount in 3 years, and have their future supply at a merely nominal price.

In boring the well the drill has passed through a variety of strata, which would be of interest to the geologist—black shale, slate, quartz, white quartz, intermixed with shining and glistening ores, and a sort of honeycomb rock, indicating the action of the tides or water. Yesterday the drill was passed through a black shale stone, and this morning it struck a dark blue stone nearly as hard as adamant.

At the depth of 80 feet they struck a ledge, and they are still at work in it, occasionally finding a thin stratum of clay. At this depth they also found water, which furnished a supply of about 50 hogsheads an hour, and pumping it out at that rate for 15 min. only lowered it 6 in. in the 5-in. bore. Not being satisfied that this would give them water enough for their works, they still kept on through the ledge to the depth of 140 ft., or 220 ft. from the surface, when they again reached water in the midst of the ledge, which now rises to within 8 ft. of the surface.

The well is now over 1,000 ft. in depth, 900 ft. of which are through solid ledge, varying of course in hardness according to the strata, but never softer than an occasional layer of slate and honeycomb stone. When the work was first commenced, a drill would last 36 hours without sharpening; now the same kind of a drill will only last one hour.

The diameter of the bore is 5½ in.; the drill is 4 in. across. The drill and iron shafting which connects it weighs now 1,200 lbs., and the rope by which it is lowered weighs 900 lbs. The machinery used for driving the drill is similar to that used in the oil regions of Pennsylvania.

The power is furnished by a 16-horse power engine, with a walking-beam of 36 in. stroke, at the rate of about 30 strokes per minute. It is the intention of the company to keep the drill at work until they obtain a sufficient volume of water for their use, unless their money gives out, or the drill goes through on the other side.—*Am. Railway Times.*

NEW BOOKS.

PLATTNER'S MANUAL OF QUALITATIVE AND QUANTITATIVE ANALYSIS WITH THE BLOW-PIPE. By PROF. T. H. RICHTER. Translated by H. B. Cornwall, A. M., assisted by J. H. Caswell, A. M. New York: D. Van Nostrand.

One of the most observable features in the history of the progress of education in this country is the rapid strides which science is making both in the lower and higher grades of instruction. Nothing is more noticeable, to those who are in the habit of either attending or delivering lectures in this country, than the eager desire both on the part of the wealthy and the poor to be considered as the possessors of some knowledge which may be called scientific, either because it is not usually possessed by their associates, or because the attainment of it leads to a real or fancied solution of some problem of more or less importance in the economy of life. This eager desire after scientific knowledge can hardly be said to be peculiar to the United States, for we find it in other countries; but it is highly characteristic of our people. The list of lectures to be delivered during the winter months in many cities and towns of the United States would rival in variety of subjects that of almost any University. The ability with which the subjects are treated varies greatly; but the variety of topics, and the more or less systematic arrangement of them, show an eagerness after general knowledge which is ever on the increase, and has already produced a very perceptible influence on our intellectual culture.

Nor is this true of what is called popular science alone. The rapid advance in the higher departments of science made in most of our institutions of learning shows a most extraordinary increase of life and vigor. It has, within the last ten years, remodelled the Sheffield School at New Haven, founded and brought to a very prominent rank the School of Mines of Columbia College in this city, and caused the Stevens Institute of Technology of Hoboken to be liberally endowed by a single individual. As we look back twenty years at the very doubtful standing which was then allowed to science in our prominent universities, we scarcely know whether to admire most the liberality which has founded these and similar scientific institutions, or the very high position which they have attained for themselves, and to which they have helped to raise science in this country.

The energy required for the foundation of such institutions necessitates the expenditure of so much vital force, that it is not surprising that we do not find the same large number of original works on various scientific subjects by American authors, that we find published in the older countries of Europe. While it is perhaps true, that there never has been a country which in so limited a time has furnished a greater number and variety of original researches, which have both aided theoretical investigations, and added so largely to the sum of human happiness, we have produced but few books which occupy prominent places in science. We point with pride to the Mineralogy and the Geology of Dana as contributions to science of which we may boast, but it must be admitted that these and a few other American works are exception productions in any country, and it would perhaps not be reasonable to expect of us, a nation with everything to create and to found, that we should dispute the palm with older nations, whose work of foundation was done long ago, and who have grown with the growth of science, while our institutions must spring into existence fully armed and equipped.

If, however, we do not produce so large a number of original works on science as older countries, we adopt into our language most of the works of high excellence, published in other countries. Its American translator has made "Wiesbach's Mechanics" almost as much a part of the English language as if it had been originally written in English. It is not without gratification that we notice that our translators of foreign works are frequently not content with rendering into English the text of the original. Translations with us, are often really new editions of the works, with modifications and improvements by both author and translator, adopted by mutual consent, so that the translation at the time of its publication, is really an edition in advance of the original, the author being, in many cases, quite as eager, or perhaps more eager to claim the translation as the original work.

A most remarkable instance of the greater value of the translation over the original work is presented in the recent publication of Richter's "Plattner's Blow-pipe Analysis." This work has, from the date of its first publication, been recognized as the only complete treatise on the subject. The fourth German edition appeared in Leipsig in 1865. The English translation just published with the co-operation of Professor Richter, is really the fifth edition of the work, since it is much more complete than the original. It has been brought by the author and translator, up to the present time. Nor can it be said to be an ordinary translation. The German has not only been rendered into good English, but the translator, and the gentleman who assisted him, are both former pupils of Professor Richter, both skilful blow-pipists, and have had several years' experience in this method of assaying ores and metallurgical products in the country. They were both engaged in giving instruction in the subject while the translations were being got ready for the press. The work has not only been brought up to the present time, but a terminology has been adopted, which is familiar to American students. The indexes to substances have been made much more complete and a general index added, which does not exist in the original. The work is therefore, not only more c mplete, but better adapted to the use of the American and English students, than the last German edition, and it must be considered as a very valuable edition to our scientific literature.

While Prof. Richter must be congratulated for having had such able translators of his work, American and English students of science are greatly indebted to the translators and publishers for having placed this remarkable book within their reach.

Pp. 1 to 56 give the description of the apparatus and reagents required for making the various tests and assays. On pp. 31-35 will be found the description of the latest apparatus invented for estimating the values of gold and silver buttons which are too small to weigh. Pp. 59-394 give the rules for blow-pipe analysis, commencing on p. 59 with the general rules to be observed. Pp. 112-394 contain a very large number of methods for examining both metallic and non-metallic substances. On pp. 380 to 394 a number of examples of methods for mixed substances are given.

These methods and examples contain every possible case, from a simple chemical salt, to those very complicated substances known as *spiess* and furnace *sows* or *bears*. The methods are so accurate, that with practice, sufficient skill may be acquired to determine with the blow-pipe the constituents of a complicated substance, with almost as much precision as by the ordinary wet method. Unfortunately there are few persons who are willing to give the time necessary for accurate determination with the blow-pipe, and no doubt the impossibility which has until recently existed, of obtaining in this country either the instruction or the instruments, has retarded the general use of the blow-pipe. The translation of this work will make it no longer a matter of surprise, that students in an examination can determine twenty-three substances in three mixtures as a test of their skill in blow-pipe manipulation.

The third section of the work, from p. 397 to the end, is devoted to the description of processes for the quantitative assay of ores, minerals, and furnace products. It will be a matter of surprise to those who do not know to what perfection these processes have been brought, to learn, that ores can be assayed with an outfit that can be carried in the pockets, and so accurately as to warrant the results being relied on in commercial operations. There are a number of metallurgical works in Europe and a few in this country where the blow-pipe is used in connection with the ordinary wet and dry assay, the results being often in favor of the accuracy of the blow-pipe. For ordinary purpose of field work in exploration, the possibility of having a complete outfit including the balance and reagents in such compass, that it can be carried in the hand, makes it a most convenient adjunct to all outfits for parties exploring new fields. There are assays in which the blow-pipe method has a real advantage over the old methods. Thus the assay of a mixture of cobalt and nickel can be made by the blow-pipe in less than two hours time, including the preparation of the assay, and quite as accurately as in the much longer and tedious wet method. The assay of gold and silver and most of the other metals can be made within an hour.

The amount of skill and practice required to make these assays is not greater than that required for ordinary assaying. They can be made any where, and require no costly installation. One reason why these assays have not come more into use is that there is an idea that continued blowing is injurious to the lungs. This is not true. The muscles of the cheeks alone are called into play and exercise. There need not be, and there ought not to be, any strain upon the lungs. In fact if there was any strain upon the lungs it would be quite impossible to make an assay. A person using the blow-pipe *must* breathe through his nose. The communication between the mouth and the lungs is completely closed except at the moment when the mouth is filled with air, and that is an instant of time. The supply of air to the lungs *must* be made through the nose. This is the proper and natural means of supplying the lungs. There is no more reason why the lungs should be strained by twenty minutes' use of the blow-pipe than by walk in the open air, of the same duration, with the mouth closed, as it should be, the supply of air to the lungs coming through the nose.

The instruments required for the examination of substances of the blow-pipe are simple and inexpensive. They have, as yet, not been easy to procure, but it is to be hoped that some American manufacturer may be induced to make them, at such a price as will place them within the reach of every student. The instruments required must be carefully made. With a large part of the instruments offered for sale, it would be impossible to perform the most ordinary blow-pipe experiment properly, and with many not at all. This is owing partly to the fact that neither those who make, nor those who sell them, understand their use. Up to this time we have been dependent on Lingke, of Freiberg, for the best apparatus made. It is to be hoped that our great superiority in mechanical skill, will enable some manufacturer to produce the instruments in this country, at such a price as to be within the reach of all.

THE WORKMAN'S MANUAL OF ENGINEERING DRAWING. By JOHN MAXTON. Lockwood & Co. For sale by Van Nostrand.

This book supplies what has long been wanted,—a good, practical, and low-priced treatise on engineering drawing. Commencing with a description of how a drawing office should be fitted up, Mr. Maxton proceeds to impart to the draughtsman a variety of valuable information concerning the materials and tools he will require to make use of, such as drawing-boards, squares, instruments, scales, colors, paper, etc. He next tells him how to prepare his paper and how to ink in his drawing, how to shade and color it, and how to border it and cut it off the board when finished, each of these subjects being treated in a separate chapter. In addition to this, there are chapters on practical geometry, projection of shadows, delineation of the slip and path of the screw propeller and paddle-wheel, on drawing tracings, for the use of engravers and photographers, and on diagrams for lectures, besides an appendix containing notes on architectural and ship drawing, and on perspective and isometrical projection, as well as on sizing, varnishing, etc. The whole is illustrated by a number of plates and by nearly 350 woodcuts.

Probably the best chapter in the book, though all are excellent, is that on the projection of shadows; commencing with the more simple shadows, such as thrown by columns, etc., Mr. Maxton proceeds, by carefully graduated steps, to show how those on various curved surfaces may be found, and his exposition of general principles is here so clear that the most inexperienced draughtsman will be able, by the aid of this part of the book, to accurately determine any shadows required in ordinary engineering drawing. The chapter in the appendix on the detail drawings of steamships also embodies many valuable hints. Although Mr. Maxton's book is intended chiefly for the instruction of students and working engineers, even accomplished draughtsmen will find in it much that will be of use to them, and a copy of it should certainly be kept for purposes of reference in every drawing office.—*Engineering.*

HANNA'S COMPLETE READY RECKONER. By J. S. HANNA. Philadelphia: J. B. Lippincott & Co. For sale by Van Nostrand.

This set of tables is of convenient size for the pocket, although the type is of good size, and the numbers liberally spaced.

The book is designed for the use of lumber inspectors and surveyors.

A TREATISE ON ENGLISH PUNCTUATION. By JOHN WILSON. New York: Woolworth, Ainsworth & Co. For sale by Van Nostrand.

This is without doubt the best treatise to be found on this subject. It is not a new book, this being the 20th edition; but this fact testifies to its widespread use.

Writers, printers, proof-readers, and copyists find in Wilson's work a valuable aid to their labor. The outward dress of the present edition is better than is usually afforded to books which are presumably in frequent use.

AN ELEMENTARY TREATISE ON STATICS. By J. W. MULCASTER, F. R. A. S., Military Tutor. London: Taylor & Francis. For sale by Van Nostrand.

This is a good book, without any of that attempt at cramming, too common now in our elementary text-books. It is calculated to give the reader a good grasp of the elements of Statics. It goes over the usual ground, states and proves the principles well and clearly, and contains in each chapter a numerous and excellent series of examples. These examples consist of "graduated and classified groups of problems each involving distinct statistical principles." These, the author says, he finds, and our experience entirely agrees with his, make "an impression on the student's mind, otherwise not attainable with problems indiscriminately taken." We gather from the book that it is the production of a good and practical teacher.

MINUTES OF PROCEEDINGS OF THE INSTITUTION OF CIVIL ENGINEERS, WITH ABSTRACTS OF THE DISCUSSIONS. Vol. XXXII. Session, 1870-71. Part II. Edited by JAMES FORREST. London: Published by the Institution.

If we were inclined to congratulate the Institution of Civil Engineers upon any especial feature more than another in their last volume of "Minutes of Proceedings," it would be upon the admirable diversity of subjects which are treated therein. It is not uncommon in serials of this character to find occasionally a particular tone pervade the whole volume. It is either too mechanical, or too much of the contents are devoted to civil engineering alone. Again, one branch of the profession may be represented in so prominent a manner as to leave others comparatively in the shade. But in the present issue, not only are the recognized and time-honored subjects, such as piers, harbors, bridges, cement, concrete, and other collateral topics of professional interest and practice discussed, but the most modern branch of engineering is brought into notice by a paper relating to the sewage of towns. The volume opens with a couple of communications, the first of which has for its object the determination of the best form of the Archimedian screw pump, and its effect when laid at different angles of tilt to the horizon; while the second is devoted to the history and construction of centrifugal pumps.—*Engineer.*

THE CIVIL ENGINEER'S POCKET-BOOK. By JOHN C. TRAUTWINE, C. E. Philadelphia: Claxton, Remsen & Haffelfinger For sale by Van Nostrand.

Mr. Trautwine's former table book served so good a purpose among the field engineers of this country, that he is already favorably known to the engineering profession.

The present book embraces formulas and tables relating to every subject which comes within the scope of an engineer's labors. Knowing the author's care and skill in such compilations, we should employ these tables with confidence.

Of the treatises upon various engineering topics with which the book also abounds, and wherein the author assumes the office of instructor, we cannot write at greater length until we have examined more leisurely.

A COMPLETE COURSE OF PROBLEMS IN PRACTICAL PLANE GEOMETRY adapted for the use of Students preparing for the Examinations conducted by the Science and Art Department in First, Second, and Third Grade "Practical Geometry." By JOHN WILLIAM PALLISER, Second Master and Lecturer of Geometrical Drawing at the Leeds School of Art and Science. London: Simpkin, Marshal & Co.

So long as Euclid was regarded as the only text-book on geometry it is not to be wondered at that a knowledge of that art should have been so little disseminated among our artisans and workmen. Outside the doors of schools and colleges there was little time and less inclination to arrive at plain and simple results by following a course of reasoning, demanding, in numerous instances, much needless verbiage and unnecessary trouble. Although no learner should study in the dark, yet it cannot be denied that, in cases where the student is engaged all day in some occupation, the capability of practically solving a geometrical question as briefly as possible is of more value than an intimate theoretical knowledge of the nature of the process.

A working man may consider himself perfectly satisfied with being able to trace out a parabola or an ellipse on paper or a platform without knowing anything about the equations to the curves. Recently many text-books on geometry have issued from the press, the aim of which has been to impart in a practical manner the principles of this essential art. Among those which unquestionably fulfil their object may be quoted the little volume before us. Each proportion is numbered separately, prefaced by a clear, terse enunciation, and the directions for solving it given in as condensed a mode as the example admits of. One especially commendable feature of the work is the excellent manner in which the diagrams are arranged. As a rule, in treatises of this description they are drawn on too small a scale, which renders the following of the working lines by the student a very difficult matter. This mistake has been altogether avoided by the author, who has had the diagrams drawn to a large scale, with bold lines so as to be readily distinguishable. The book is intended to serve as a guide to those who intend to be candidates at the Government examinations, and we can only observe that if they should not pass in this particular subject it will not be the fault of Mr. Palliser's treatise.—*Engineer.*

MISCELLANEOUS.

Hirsch's Patent Screw Propeller.—We make the following extract from a printed report of Ernest Voss (engineer), of the performance of Hirsch's Patent Screw Propeller on steamship Prins Van Orange, during her trip from the Clyde to Holland :

"The performance of the S. S. Prins van Orange and her engines during the voyage from the Clyde to Nienwedeep will, at the first glance, be perceived as favorable, when it is observed that the whole voyage from the Clyde to Nienwedeep only lasted 74 hours, namely, from the 8th July, 6.30 P.M. till 11th, 8.3 P.M., when we arrived on the roads of Nienwedeep. The distance run is 800 miles, and taking into account the stoppages for putting pilot on shore, and making soundings, besides the time lost in going with half engine-power on account of a dense fog at the north of Scotland, it will be seen that the average speed of the ship reached the considerable height of 11 knots per hour.

"The vessel had a mean draft of 16 ft. 1 in. having an immersion of 15 ft. 6 in. forward, and of 16 ft. 8 in. aft, which of course is only a light draft, and is no doubt in favor of speed, as the midship section as well as the wet surface of the ship, the factors of resistance, are accordingly less. But at the same time we must not lose sight of the fact, that at a draught of 16 ft. 8 in. aft, the propeller is not perfectly immersed; the blades project nearly a foot over the water's surface, so that the propeller cannot utilize the full effect of the power transmitted by the engines.

"The coal consumption for the whole voyage was 72 tons, or a little less than 24 tons per day, which means 1 ton per hour.

"According to indicator diagrams taken during the voyage the engines developed a power of 1150 H P., and taking this into consideration with the coal consumption, it shows that the engines used less than 2 lbs. per indicated H P. per hour, which is certainly a most satisfactory result. For further demonstration of the comparative splendid performance of ship and engines, I wish to give the co-efficient, according to the following formula :

$$C = \frac{V^3 \times m}{P}$$

where V is velocity of ship in knots ; m = midships area (548 sq. ft.), and P the indicated horse-power ; C the coefficient, which is variable for different ships. For mail steamers the coefficient is considered as very satisfactory at 70 ; In our case I find it to be 634, which I think is a very good result."

The Prins Van Orange and her sister ship Willem III, were built by John Elder & Co., the latter differing only in her propeller, which is of the common kind.

The following figures, placed in juxtaposition, will give a comparative view of the voyages of the two vessels from the Clyde to Holland, and as a consequence, also an estimate of the relative performance of the screw propellers fitted respectively to these vessels :

	Willem III.	Prins van Orange.
Draft of vessel—mean	18′ 2″	16′ 1″
" " forward	16′ 9″	15′ 6″
" " aft, for immersion of screw	19′ 6″	16′ 8″
Immersed midship section	628	548
Distance run in miles	840	800
Duration of voyage in hours	84	74
Total coal consumption	81	72
" " reduced to 800 miles.	77	72
$C = \frac{V^3 \times m}{\text{coal consump.}}$	8156	10130
Kind of propeller	Common.	Hirsch's Patent.
Pitch of "	21	23
Revolutions of ditto per minute.	57	53
Slip of screw per cent	15 2	8.6
Speed of ship in knots	10	11

Some time has passed since anything was heard of measures to be taken for checking the course of the Tiber. A commission has been deliberating on this subject since last winter, and has only lately presented its report. The following are the principal recommendations it makes:—(1) To reduce the arches of the bridges, so as to give freer course to the river when swollen (a system adopted in the construction of bridges over the Po and the Adige); (2) to clear out the bed of river, removing all the rubbish of centuries; (3) to cause all the sewers of the city to flow into one common sewer on either side of the river, which *cloacæ maximæ* are to be carried out to Santo Paolo; (4) to construct a Lungo Tevere (embankment) similar to that of the Lung' Arno of the Thames in order to check and guide the stream and offer a promenade for the public; (5) to divert the course of the Tiber. It is proposed to commence operations near the Ponte Molle, and carry the river round behind St. Angelo, and nearer the church of St Peter. The report has not yet been approved and whether projects of so vast a character will ever be accomplished is doubtful—at all events a long time must elapse before this can be done.

Weather Signals of United States Signal Service.—The signal is a square red flag, with a square centre of black, for denoting danger by day, and a red lantern to denote danger by night. It is highly important for the public fully and at once to know, that the Signal office will display only one signal, and that one signal will be elevated only in the case of probable danger There will be no safety signal.

We give below, however, the official text, which, if carefully weighed and pondered, can leave no uncertainty in the mind of any one, as to the meaning and use of the signal.

The Cautionary Signal.—The cautionary signal of the Signal Service, United States army—a red flag with black square in the centre by day, and a red light by night—displayed at the office of the observer, and other prominent places throughout any city, signifies:

1. That from the information had at the Central Office in Washington, a probability of stormy or dangerous weather has been deduced for the port or place at which the cautionary signal is displayed, or in that vicinity.

2. That the danger appears to be so great as to demand precaution on the part of navigators and others interested—such as an examination of vessels or other structures to be endangered by a storm—the inspection of crews, rigging, etc., and general preparation for rough weather.

3. It calls for frequent examination of local barometers, and other instruments, by ship captains, or others interested, and the study of local signs of the weather, as clouds, etc., etc. By this means those who are expert may often be confirmed as to the need of the precaution to which the cautionary signal calls attention, or may determine that the danger is overestimated or past.

This red flag or red light known as the cautionary signal, is displayed when the information in the possession of the office induces the belief that dangerous winds are approaching.

This term, dangerous winds, has a meaning varying somewhat with the locality in which the winds occur. Thus, the severe gales of the Atlantic Ocean, which sometimes attain the hurricane velocity of 50, 60 or 70 miles an hour, are seldom equalled on the lakes. But on the lakes, where the sea room is limited, winds that are reported from the lake coast as "brisk" (*i. e.*, from 15 to 25 miles an hour, in which a ship on the ocean would carry all her canvas,) frequently become dangerous to navigation. Moreover, it is important to remember, also, that the direction of the wind often determines whether it is to be dreaded. Experience demonstrates that most danger is to be apprehended when the wind is blowing on to a lee shore. The cautionary signal might, therefore, be properly expected only for ports thus threatened. For inland, and well-sheltered points, as Baltimore and Philadelphia this distinction cannot be easily made. It has, therefore, been decided that the cautionary signal shall be hoisted whenever the winds are expected to be as high as twenty-five miles an hour, and to continue at that velocity for several hours, within a radius of 100 miles of the station.

Comparative Efficiency of different kinds of Boiler Plates for Steam Generation: We find in a late number of the "Scientific American" a a valuable report on the above subject by Messrs. Whelpley and Storer of Boston. We copy the following:

"None of the various causes which engineers have assigned for the wide differences in the evaporative powers of boilers have seemed to be sufficient and conclusive; and some other important element of variation has long been suspected by those who have given thought to the matter.

In order to discover this hitherto unknown cause, a series of experiments was made, based on the supposition that the conditions which affect the conducting power of a metal for electricity—alloys and impurities—would, perhaps in equal degrees, affect its power for transmission of heat.

"It was evident that all previous estimates of comparative values of fuels, modes of firing, and styles of boilers (the universally recognized causes of variation), would be subject to careful revision if it could be demonstrated that the most important source of error had hitherto been overlooked. The accepted standard results would become valueless.

"Nine pieces of boiler plates of different brands were selected for the purpose of the experiment; they were of uniform thickness (5-16ths of an in.). Some of them were samples of locomotive fire-box plate, and the others of boiler-plate.

"They were tested for their heat transmitting and steam generating efficiency, with the following results: Allowing the plate of lowest transmitting power to have a value of 100, we have

1	Power of transmission	100
2	" " "	104.4
3	" " "	117 7
4	" " "	118 8
5	" " "	121
6	" " "	123
7	" " "	123 3
8	" " "	141 9
9	" " "	144

"It must be distinctly understood that these transmitting powers were measured by the generation of steam under equal and similar conditions. Each plate was subjected to a number of trials; the temperature of the flame to which it was exposed varying, during each series of trials, but a very few degrees from 550 deg Fahr., and the time of evaporation of the water but a few seconds.

"The ratios of values have been calculated according to the tables for such purposes prepared by Dulong. The experiments have been conducted under our direction and immediate supervision by Mr. Charles E. Avery, of Boston, a gentleman thoroughly competent by scientific and practical knowledge for the undertaking of such delicate work.

"In order to discover and avoid all sources of error, the apparatus and method finally adopted for these determinations were first subjected to the test of weeks of most careful experiment.

"To generate an equal amount of steam in equal times and with similar conditions of fuel and draft, boilers made of Nos. 8 and 9 plates would consume *constantly* 40 per cent. less fuel than boilers made of plates Nos. 1 and 2.

"Insomuch, therefore, as their efficiency in the production of steam is vastly greater than that of the inferior plates, the commercial values of these plates will be still greater in proportion. The possibility of a daily economy of 40 per cent. of fuel should induce boiler users to purchase the best plate and boiler plate manufacturers to exercise more care in its manufacture.

"Some of the most considerable variations in evaporative efficiency were found between plates from the same manufactory.

"No analyses of the iron of the plates have been made, it having been assumed that the comparative presence or absence of slag or glass—a poor conductor of heat—was the chief cause of the determined variations; though, doubtless, carbon and other elements will be found to exercise decided influences. These we propose to determine; and other points of novelty and interest in regard to boiler plates have been decided, which we hope at some future day to give to the public.

"With our method of firing (our application of pulverized fuel to the generation of steam), which almost entirely eliminates other causes of variation, we had found one boiler to have an evaporative efficiency of nearly 60 per cent. more than another. Hence the search for the unknown causes of variation."

Intermittent Filtration.—Mr. Bailey Denton's system of downward intermittent filtration has been tested at Merthyr. The local paper remarks on the subject:—"The public are by this time aware that the system of purification adopted on the land below Troedyrhiw is not irrigation, but a scheme devised by Mr. J. Bailey Denton, the engineer appointed by the Court of Chancery, which he calls intermittent downward filtration. Twenty acres of land have been parcelled out into four panels of equal areas. The whole piece has been drained to a depth varying from 4 to 7 feet, the drains serving the double purpose of collecting and carrying off the subsoil water and the sewage water. The surface of each panel has been carefully prepared for the equal distribution of liquids. The sewage, after being turned on to the land, is left to find its way by percolation or filtration to the drains beneath, the theory being, that in its passage through such a depth of soil, by the time it drops into the drains it has become thoroughly purified—all its offensive solids being left behind and the noxious elements held in solution being decomposed and absorbed by the deodorizing power of the soil, of which the sewage is thus made the incessant fertilizer. The Commissioners first visited the adit of the sewer where the sewage is discharged into the distributing conduits, and half-hourly samples were taken for subsequent analysis. There was only a slight smell as the sewer was opened, and as the sewage flowed over the soil it disappeared—there being an entire absence of odor in walking round the beds. The crops now growing, consisting of turnips, mangolds, cabbages, savoys, Brussels sprouts, broccoli, and winter greens of various kinds, were really of magnificent growth, and excited the greatest interest in the visitors, who mentioned a fact of which it is to be hoped that somebody in this neighborhood may take advantage, namely, that the sewage farms near London not only supply their own neighborhoods with cabbages, but find a market for tens of thousands of them in Birmingham, and even send them so far as Manchester. After traversing the grounds, the Commissioners arrived at the outlet of the subterranean drains, where there was a large volume of the clearest water flowing—an undeniable proof of the efficacy of the system. Samples of the water were taken at half-hourly intervals for analysis. It was said that the laborers on the ground quenched their thirst regularly at this stream, and by way of showing their faith in its purity, many of those present *tasted* the water, which has a very strong chalybeate flavor, and certain indications of the presence of iron. But Dr. Paul has already analyzed it, and says in effect that it would be a boon to the Londoners if they could get drinking water of equal purity. To look at it, one might lay a wager that clearer water never flowed in the Taff."—*Mechanics' Magazine.*

Xylonite.—Xylonite is a substance of which the chief ingredient is chemically allied to gun-cotton, being formed by the nitric acid upon woody fibre. One of the chief uses to which it is applied is for making impermeable sheeting; and if all that is said about it bears the test of experience, it bids fair to take the place of india-rubber. Different samples of waterproof fabrics vary in substance from a thin trsnsparenf tissue up to a thick, strong cloth suitable for water-beds, water-cushions and other articles where strength of fabric is all important. Xylonite has several advantages over india-rubber. It is not affected by a boiling temperature, and can be readily washed in soap and water and ironed like ordinary linen or cotton fabrics. It is not acted upon by oil or grease. Xylonite materials can be made of any color, are considerably cheaper than similar gutta-percha or india-rubber fabrics, can be used again and again, and can be kept in store for any length of time without deterioration.—*London Lancet.*

Asphalt Roads in Paris.—It is stated that the authorities of Paris are about to give up the asphalt paving, and return to the old-fashioned stones, in consequence of the great expense of keeping up the former. The determination of the Parisians is not encouraging, but then it must be remembered that we are not quite so ready to use our paving-stones for the manufacture of barricades as they are.

The Decimal System in Austria.—The Austro-Hungarian Government have at last resolved to adopt the decimal system throughout that empire, and that measure is to become legal after the 1st January, 1873.

Apparatus for Measuring the Radiant intensity transmitted by Flames.

Constructed by CAPTAIN JOHN ERICSSON.

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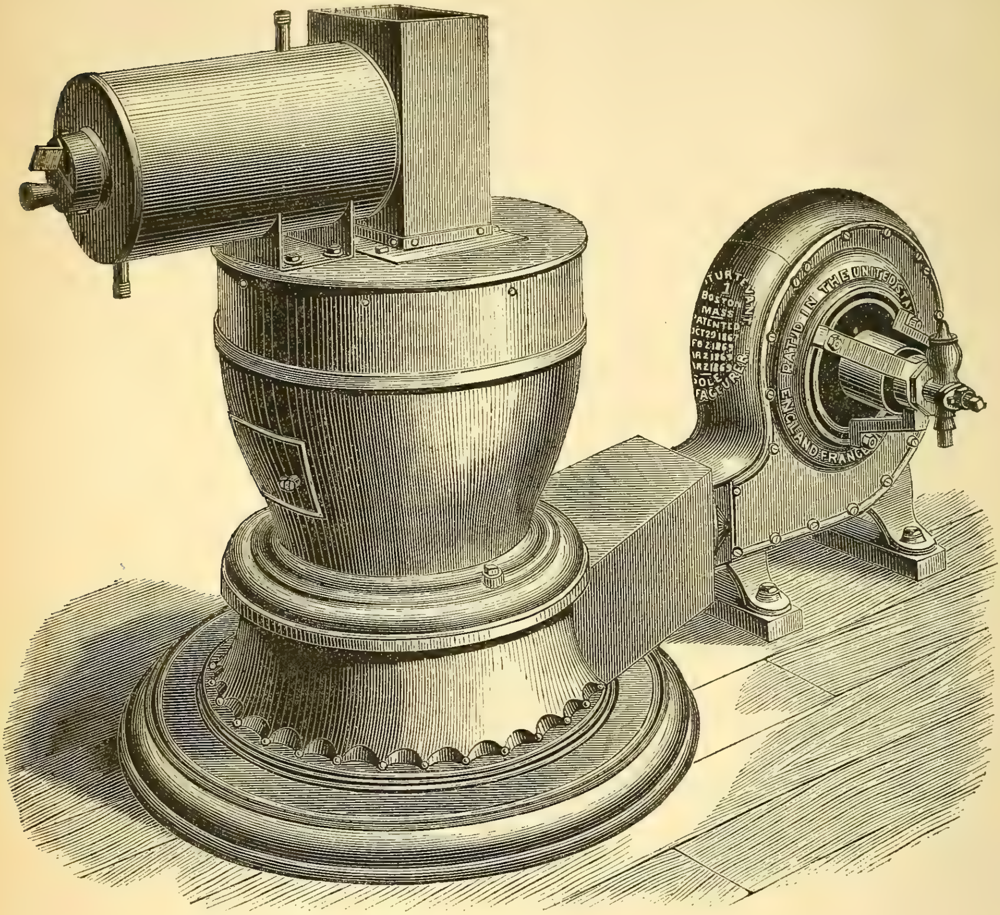

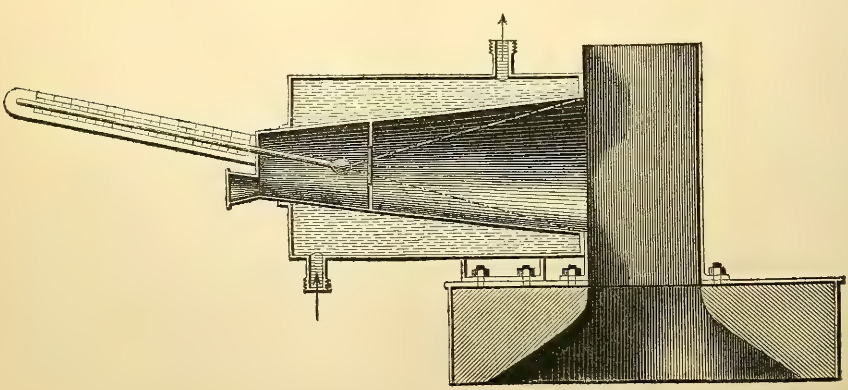

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RADIANT HEAT TRANSMITTED BY FLAMES.

By CAPTAIN JOHN ERICSSON.

From "Engineering."

The temperature produced by the radiation of flames, is a subject of far greater importance than generally supposed. Some distinguished physicists imagine that the radiant power of flames is considerably less than that of incandescent solid substances, contending that it is impossible to ascertain the temperature of the sun because the radiant heat transmitted is the result of the radiation of the incandescent gases of the photosphere. The accompanying illustration, Fig. 1, represents an apparatus originally constructed to demonstrate the unsoundness of this assumption, and to prove that the radiant power of flame is not less than that of incandescent solid bodies. In a practical point of view, an exact knowledge of the temperature produced by the radiant heat transmitted by flames, is of great importance, as it furnishes means of measuring, with desirable precision, temperatures which the nature of the materials at our command renders it impossible to ascertain by direct contact. It was shown in the article on Solar Heat, published in "Engineering," December 30, 1870, that the intensities of circular radiators of *different* size, imparting equal temperature at *equal* distance from the radiating surface, are inversely as the squares of the sines of half of the subtended angles, that is, the angles formed by the axes of the circular radiant surfaces and the heat rays projected from the circumferences to the substance receiving the radiant heat, in the prolongation of the axes. It will be evident on reflection that, agreeably to this proposition, it is possible to determine the temperature of an inaccessible circular radiator *without knowing its size or distance.* The method of measuring temperature, which we are going to consider, depending solely on the correctness of the paradoxical proposition just stated, it will be necessary to subject the latter to some test of a practical nature before we proceed to examine in detail the device by which the radiant intensity, transmitted by a flame, is rendered subservient in determining its temperature. It will be seen by referring to the description of the solar pyrometer, contained in the article before referred to, that the radiant heat transmitted from a circular radiator of known size to the bulb of a thermometer applied at a known distance, within a vacuum, has been ascertained with critical nicety. It has been shown that, with an angle of 16 deg. 8 min. subtended by the axis of the radiator and the heat rays projected from the circumference towards the bulb, the temperature of the radiator will be 12.91 times that indicated by the thermometer receiving the radiant heat. This fixed relation between the angle subtended and the temperature transmitted is evidently of the utmost importance. In connection with the fact already noticed, that the intensities of radiators of different size are inversely as the squares of the sines of the subtended angles, it enables us to apply the proposed practical test in support of the assertion, that the temperature of an inaccessible radiator may be determined without ascertaining its size or distance. Astronomy furnishes the information that the angle subtended by a line drawn from the circumference of the sun, and a line drawn from its centre towards the earth when the latter is in aphelion, is very nearly 15 min. 46 sec. The corresponding angle subtended by the radiator of the solar pyrometer and its axis being 16 deg. 8 min., it will be found by an easy calculation that the square of the sine of the angle subtended by the sun, is to the square of the corresponding sine of the radiator of the pyrometer as 1:3685.71. The experiments with this instrument having established the fact before stated, that the intensity of the radiating surface is 12.91 times greater than the temperature transmitted to the focal thermometer, it will be readily perceived that in order to raise the focal temperature to 84.84 deg. the temperature of the radiator must be $84.84 \times 12.91 = 1095.28$ deg. And if we suppose its diameter to be reduced to such an extent that it subtends an angle of only 15 min. 46 sec., like that subtended by the sun, it will be obvious that its temperature, owing to the small radiating surface, must be vastly increased to transmit a temperature of 84.84 deg. to the focal thermometer. The foregoing explanation having demonstrated that the increase of temperature required under the stated conditions, will be inversely as the sines of the subtended angles, viz., 3685.71: 1, it will be seen that the temperature of the diminished radiator must be 3685.71×1095.28 deg.=4,036,884 deg. in order to transmit the stated temperature of 84.84 deg. to the focal thermometer. It scarcely needs explanation that the temperature last mentioned has been selected as a basis of our calculations, on the ground that the intensity of solar radiation is 84.84 deg. at the boundary of the atmosphere when the earth is in aphelion, in which position, it will be recollected, the before-mentioned angle—15 min. 46 sec.—is subtended. Consequently, the temperature of the sun, deduced from the data furnished by the results of the experiments with the solar pyrometer, without reference to the sun's distance or size, will be 4,036,884 deg. Now, computations based on the sun's distance and diameter, in accordance with the theory that the temperature produced by radiant heat is inversely as the areas over which the rays are dispersed, in connection with the ascertained intensity of solar radiation at the boundary of the terrestrial atmosphere, show that the temperature of the sun at the surface of the photosphere somewhat exceeds 4,035,500 deg. (See demonstration, vol. iv. p. 125) Considering this close agreement between the results arrived at by methods totally different, and considering the severity of the test applied, that of comparing the effect of radiant heat at a distance of 18 in., to that acting through a space exceeding 90,000,000 miles, we cannot question the soundness of the doctrine enunciated at the commencement of our discourse, nor question the practicability of measuring the temperatures of distant inaccessible bodies without knowing their size or distance. The important fact should not be overlooked that our demonstration relates only to the temperature of *circular* radiators. But it will be shown hereafter that the temperature of radiators of an irregular form, whether consisting of incandescent metallic bodies or flames, may also be ascertained, irrespective of the distance and size of the radiating surface, provided that distance be short.

Before examining the adopted expedients of measuring the temperature transmitted by the radiation of flames, it will be necessary to consider their composition. Professor Draper, who has closely investigated the subject, states that the flame of a lamp consists of three principal divisions: First. A central nucleus which is not luminous, and consists of combustible vapor. Secondly. An intermediate portion, the true flame, arising from the reaction of the air and the combustible vapor, and being composed of a succesion of superposed shells, the interior being red, the exterior violet, and the intervening ones colored in the proper order of refrangibility; the cause of this difference of color being the declining activity with which the combustion goes on deeper and deeper in the flame. As to temperature, Professor Draper considers that the inner red shell cannot be less than 977 deg. Fahr., and the exterior violet one probably more than

2,500 deg. Fahr. Thirdly. An envelope consisting of the products of combustion, exterior to the true flame, shining simply as an incandescent body, and its light for the most part overpowered by the brighter portion within. Apart from the difficulty of giving to such a flame as the one described the form necessary to render exact measurement of its radiant power possible, the result would be of little value owing to the want of homogeneity and uniformity of temperature. Our investigation, therefore, will be confined to what may be termed solid flames of uniform temperature throughout the mass, such, for instance, as the flames of reverberatory furnaces and cupolas surrounded by walls that prevent the action of the exterior atmosphere. Evidently, if we can ascertain what intensity of flame is indispensable to fuse a metal, we at the same time ascertain the temperature of the fused metal itself. It will be reserved for a future occasion, to present a delineation and description of an instrument by means of which the temperature of such flames may be measured for practical purposes; our present object is simply that of answering the theoretical question, Is the temperature transmitted by solid flames equal to, or less than that transmitted by incandescent metallic bodies? The reader will bear in mind that this investigation was originally undertaken to refute the assertion of certain savants, that the temperature of the sun cannot be ascertained because the radiant power of incandescent gases is less than that of incandescent solid matter.

Fig. 1 represents a conical furnace provided with a grate applied at the contracted lower portion, admitting of a free passage of the air over the entire surface. A capacious chamber is formed under the grate, into which air is forced by an ordi nary Sturtevant centrifugal blower. The internal portion of the furnace is contracted towards the top, as shown in Fig. 2, terminating with a square opening, over which is placed a square trunk corresponding exactly with the said opening. The furnace being charged with combustibles that readily ignite, it will be evident that a moderate speed of the blower will, soon after ignition, fill the square trunk with a solid flame of perfectly uniform temperature throughout, contact with the exterior atmosphere being wholly prevented, while the air which supports the combustion is subdivided almost infinitely, and uniformly dispersed, through the mass of burning fuel. A chimney of very large section, equal to that of the contracted part of the furnace, being applied above the square trunk, any tendency to pressure and accumulation in the same will be effectually prevented. A solid flame of uniform temperature having thus been obtained, its radiant power has been ascertained by the following device. A conical vessel open at the large end, surrounded with a water jacket of cylindrical form, shown in Fig. 2, is secured to the square trunk, a circular opening being formed in the side of the latter, corresponding with the open end of the conical vessel. Referring to Fig. 2, it will be seen that a perforated diaphragm (composed of polished silver) is introduced near the small end of the conical vessel. A thermometer is applied near the circular perforation of the diaphragm, the bulb being placed exactly in the centre line of the vessel. An opening, surrounded with a short conical tube, covered with a piece of mica, affords a view of the interior of the conical vessel. The water-jacket is supplied from the street main, a constant stream being kept up during experiments. The application of a chimney of large diameter above the square flame-trunk, and the covering of the short conical tube with mica, as stated, in order to prevent any current of heated air or gas through the conical vessel, have contributed to secure the desired result. A disk of flame of uniform brightness, the color varying with the speed of the blower, has been successfully produced. Respecting the experiments which have been instituted, it may be briefly stated that, when the blower is worked at the most advantageous speed for producing a flame of maximum brightness, the thermometer exposed to its radiant heat indicates 282 deg., while the temperature of the water circulating through the external casing is 73 deg. Hence, the heat transmitted to the enclosed thermometer by the radiation of the flame produces an augmentation of temperature of 282—73=209 deg. Fahr. The angle subtended by the centre line of the conical vessel and lines drawn from the circumference of the flame-disk to the bulb of the thermometer, being 16 deg. 8 min., precisely as in the solar pyrometer, we know that its temperature must be 12.91 times greater than that indicated by the inclosed thermometer. Accordingly, the temperature of the flame passing from the furnace through the square trunk into the chimney will be $12.91 \times 209 = 2,698$ deg. Fahr., a result corresponding very nearly with ordinary pyrometer indications; a fact, however, of little importance in view of the uncertainty of such indications. It will be supposed that the stated high temperature of the flame must at once destroy the square trunk. Such, however, is not the case, from the reason that the trunk is made of plate-iron only 1-16 in. thick, the radiation of which is so rapid that the gases composing the flame—these gases being slow conductors—cannot communicate the heat as fast as it is carried off by radiation. The top of the furnace at the point where the flame is concentrated and conducted into the square trunk, being exposed to intense heat, is lined with fireclay. It should be observed that the apparatus is exposed to a high temperature only while the blower is in operation, the motion being stopped as soon as the internal thermometer reaches maximum indication.

It will be noticed by those who have attentively studied the article on radiant heat published in a former number of this magazine, that, unless the radiant surface forms a spherical concavity, the focus of which coincides with the centre of the bulb of the recording thermometer, the indication will not be exact. The flame-disk being *circular*, this objection is overcome by removing the thermometer from the face of the flame to such a distance, that the mean length of the heat rays transmitted to the bulb corresponds with the radius of a concave radiator of the same diameter as the flame-disk, subtending the before-named angle of 16 deg. 8 min. As already mentioned, the consideration of the *practical application* of the principle developed by the apparatus represented by our illustration, almost self-evident to constructive minds, has been reserved for another occasion. In the meantime engineers will be interested to learn that instruments are being constructed by means of which the temperature of metals, of any temperature, may be measured with positive accuracy by simply ascertaining their radiant power at a convenient but unknown distance.

AN UNWRITTEN CHAPTER OF THE METALLURGY OF IRON.

By ROBERT MALLET.

From "The Engineer."

Probably the oldest pieces of iron forged by the hand of man, which have reached our time, may be the sickle blade found by Belzoni, under the base of a granite sphinx at Karnak; the sheet, or possibly blade, of some sort found by Colonel Howard Vyse, embedded in the masonry of the Great Pyramid, and revealed after a blast of which Mr. St. John V. Day, C. E., has read an interesting account this year before the Philosophical Society of Glasgow; and the larger portion of a cross-cut saw, exhumed by Mr. Layard at Nimrood, all of which are now in the British Museum. Assuming the Pyramid to have been in existence 2,000 years before our era, and that the metallic arts must have had some centuries of incubation and improvement in Egypt previously, this blade, embedded in the huge ashlar work of the Pyramid, brings back the working of iron or steel, and the abundance of either of these bodies, such that common tools were made of them in Egypt, to an epoch from 4,000 to 4,500 years before the present time. Though Egypt be still supposed the country in which the earliest historical monuments, and historical or *quasi* historical records of our race have been found, it neither follows nor seems probable that its technical arts originated and were perfected wholly within its own borders; the cradle of its arts as well as of its inhabitants, was somewhere else, and everything points for those to some still remoter East.

Without attempting to follow link by link the chain of evidence—such as it is, and at many points obscure—we may venture to believe that the knowledge of working in iron reached Egypt from the East, and had, if not its origin, yet its earliest practice in the high lands of Central Asia; and, if so, allowing time for its migration westwards and southwards, iron working was known in Asia 5,000, or perhaps 5,500 years ago. Nor does even this reach or give any indication of the actual origin of the art, or of the discovery that must have preceded it. Some Tubal Cain there must have been, who first found that the brittle and unglistening piece of heavy red or brown stone, or compact clay, could, by heating and hammering, be brought to the state of a much heavier black, hard, and tough mass, extensible only by blows while hot, and having, when broken or ground upon a stone, whiteness and metallic lustre. But there may have been—indeed, it is almost certain there were—many Tubal Cains, *i. e.*, many such independent discoverers, differing in time, and living at widely apart points of our globe.

The rare use of iron amongst the Esquimaux and some negro tribes of Western Africa, obtained from reputed meteoric iron, though perhaps very ancient, cannot on good grounds be supposed, as it has been, to have suggested the working in iron to all the rest of the world.

Suppose the fact known, the next step is too great. What link is there to connect the bright mottled meteoric iron with any red or brown stone, little differing from every clod the uncultured man trode upon? The true origin of iron working from its ores must have been in a country rich in timber fuel, with red or brown hematites abundantly showing themselves, and peopled by a race endowed with the higher intellectual faculties, and already advanced beyond the savage state.

All those conditions existed at periods remote beyond tradition in Central Asia; indeed, they exist at the present moment at many centres north and south of the Himalayas. But they also, in all probability, existed at equally and possibly still more remote epochs in those vast regions of far Eastern Asia that we roughly comprehend under the name of China.

The pre-historic archæology of this part of the earth yet remains to be explored. China must have had its period of troglodite caves and stone instruments, but with a horizon in time almost unimaginably higher than those ages of which the *vestigia* have been discovered in Europe; for China presents evidences of a civilization, distinctive, earlier, longer, and greater than that of any other Asiatic or European nation.

Iron-making may have been independently discovered in Central Asia, but it may also, and with more probability, have travelled there from the ancient peoples of the remotest east of that continent; and if so, its earliest traceable epoch, again allowing time for migration, would mount to an antiquity equal to or exceeding that of the whole vulgar chronology of mankind, which fixes the age of the world at about 6,000 years.

If these views be admitted, the most ancient fragments of iron or steel extant are aged but about half of the vast period that has elapsed since iron, with more or less probability of proof, has been known to man as a manufacture; and how much higher still in time may have been the discovery of the metal itself by some primordial Tubal Cain, we have no present means of even conjecturing.

The object of this article, however, is not to discuss the origin of iron-working, except in so far as it is needed to indicate the amazing periods during which it has been practised in Asia, with a view to pointing out, by one or two striking examples, how extremely imperfect is our knowledge of the phases through which this ancient Oriental metallurgy has passed; that it has not been always, as is the common belief, what we see it now in India, and that within the comparatively short period of a few centuries past, working in iron was carried on in India upon a scale so stupendous as to rival the productions of our largest steam-hammer forges in the Europe of to-day.

It is strange that of the iron metallurgy of Asia, the mother land of all the arts, of India, the country where, more than 20 centuries ago, King Porus presented to Alexander the Great *apacka*, or wrought bar of Damascene steel, just as Homer's Achilles offered for a prize at the funeral games of Patroclus a like valued mass; whence the Greeks obtained the like material for their "wonder-working sword blades" (*θαυμασια ζίφη*); where steel dies were employed for coinage when our own ancestors were naked savages; of China, whence *cast-iron* hollow vessels now reach us of a combined magnitude and thinness, that we have not yet been able to imitate or even to imagine the process by which they are cast, and razor steel said to surpass all European steel in temper and durability of edge,—less is known than of the iron working of any other parts of the more or less civilized world; yet such is the fact.

Central Asia, and even China, as yet are nearly *terræ incognitæ*; but India south of the Himalayas has been more or less open to European observation for centuries, and has been in our own power for more than one. How little is known of the working of iron in China may be gathered from the bald and imperfect accounts of it given (pp. 52-58) by MM. Stanislas Julien, Mem. Inst., and Paul Champion, Preparateur au Conserv. des Arts et Metiers, in their work on the "Technical Arts of the Chinese Empire," published in Paris in 1869; the first named author having a reputation as one of the first Chinese scholars in Europe, and the second being a competent metallurgist and technologist. Yet China possesses the knowledge of working in *fluid cast iron*, as well as in wrought iron and steel—the first being, at the present day, at least, commonly reputed to be unknown in India, where wrought iron is made direct from the ore, and steel also.

A *résumé* of the methods of working iron in India, which is probably the best that exists in English, has been given by Dr. Percy, in his "Metallurgy of Iron," but it is all comprised in about twenty pages, and though a good deal of scattered information on the subject may be found elsewhere, it probably would add but little of importance to what he has collected.

Dr. Percy, however, passes by the historical side of the subject altogether, or contents himself with the following paragraph as to it, with which his statements open (p. 254): "The Hindoos appear to have carried on the *direct process* (*i. e.*, making *wrought iron* direct, without it passing through the *indirect* stage of cast iron) from time immemorial, as we may infer from the large accumulations of slag which occur in various localities in India; and as it is scarcely possible to imagine anything more rude than their appliances, or anything more diminutive than their scale of operations, it would seem that they have not made any substantial progress in the art, at least in many districts. Their furnaces are frequently not larger than a chimney pot, and hours of incessant toil are sometimes required to produce a few pounds weight of iron." This may be taken as a rough account of the present state of iron working in India. But without going back so far as "time immemorial," the facts now to be adduced prove it to be a very incomplete, or rather inaccurate view of the history of iron working in India only a few centuries back.

Within the cincture of the ancient mosque of the Kutub, situate near Delhi (so named from the celebrated and grandly lofty Kutub minar forming part of the mosque), and not far from the principal gate, exists a wrought-iron pillar. This wrought-iron pillar is as large as the screw shaft of one of our first class steamships, and a forging of the same size would be deemed a piece of first class work for any one of our great steam hammer forges in Europe, and yet it is more than 1,000 years old, and may be as much as 1,500. Its form is either that of a conic frustrum or of some curvilinear spindle, giving it a very slight swell towards its mid-height. The capital consists of an elaborate Indian design, the whole of which good observers deem to have been carved by the chisel out of the solid iron. The shaft to near the present ground level is beautifully smooth and true, and presents the character of having been "swaged," or, if not, "sledge planished" to its finished form. The lower part for 3 or 4 ft. above the present ground, and below it, is rough and but carelessly rounded; there appear to be some rather large cavities in this part of the shaft. This pillar has been known to Europeans for many years. The earliest printed notice of it which the writer has seen is in the "Journal of the Asiatic Society of Bengal," vol. vii., p. 659, *et seq.*, being part of a memoir "On Lithographs and Translations of Inscriptions," taken in Ectype, by Captain T. S. Burt, Engineer. A much more extended account may be found in vol. xxxiii. after p. 612 of the supplement to the same journal, forming part of the Report of the Archæological Surveyor to the Government of India for the season of 1862–63.

The dimensions of the pillar may be approximated from paint marks in a vertical line placed upon it, at distances of 12 in. apart, which have transferred themselves to the photograph. The following are those given by the Archæological Surveyor, above referred to, at p. 34, etc.: "The total height above ground is 22 ft., that of the capital 3½ ft., and that of the rough part near the ground the same. But its depth under ground is considerably greater than its height above ground, as a recent excavation was carried down to 26 ft. without reaching the foundation on which the pillar rests. The whole length of the iron pillar is, therefore, upwards of 48 ft., but how much more is not known, although it must be considerable, as the pillar is said not to be loosened by the excavations. I think, therefore, it is highly probable that the whole length is not less than 60 ft. The lower diameter of the shaft is 16.4 in. and the upper diameter is 12.05 in., the diminution being 0.29 in. per foot. The pillar contains about 80 cubic feet of metal, and weighs upwards of 17 tons."

There may be some doubt as to the correctness of the great depth underground assigned here, but the dimensions above ground seem reliable, and are from actual measurement. The total weight assigned seems somewhat in excess, even on this author's assumption as to length. An inscription of 6 lines exists on the pillar itself, about half-way of its height, which records in fact all that is known as to its history. Of this Captain Burt gives the following account :—" The principal inscription on the Delhi iron pillar is in Sanscrit, the character that form of Nagari which has been assigned to the 3d or 4th century of the Christian era. * * * * The curves of the letters being squared off, perhaps on account of their having been *punched* upon the surface of the iron shaft with a short *cheni* (punch) of steel and a hammer, as the actual engraving of them would have been a work of considerable labor." The inscription itself is of the most disappointing sort—its purport is merely to record that "a prince, whom nobody ever heard of before, of the name of Dhava, erected it in commemoration of his victorious prowess ; thst he was of the Vaishnair (Hindoo) faith, occupied the throne he had acquired (at Hastinapura ?) for many years, and seems to have died before the monument was completed ; as no royal ancestry is mentioned he was probably an usurper." A transcript of this inscription, showing the squared letters, exists in vol. vii. of the " Journal of Royal Asiatic Society," and in vol. xxxiii. of same a copious mass of archæology and mythology bearing upon it, which those interested in those branches of knowledge can consult. Our business with the pillar is exclusively as a metallurgic monument.

The data of its production is, as we have seen, fixed by the inscription as the 3d or 4th century, A. D. Its form and chief dimensions are before us. Now what is the material of the pillar, for upon this depends the nature of the processes by which it must have been made ; is it of cast iron or of wrought iron ? As to this the evidence is as yet not absolutely decisive.

The Archæological Surveyor, in his report above referred to, appears to have thought it to be cast iron ; he says, " The Delhi pillar is a solid shaft of *mixed metal.* * * * * * There are flaws in many parts which show that the casting is imperfect, but when we consider the extreme difficulty of manufacturing a pillar of such vast dimensions, our wonder will not be diminished by knowing that the casting of the bar is defective,"—p. 34. What this writer means by mixed metal it is hard to conjecture ; he obviously had no knowledge of practical metallurgy, and his opinion must pass for what it may. Captain Burt, who appears to have had some such practical knowledge, obviously deems the pillar to be of wrought or forged iron, and supports that opinion by his ingenious and practical remarks as to the punching on it of the inscription. This latter view receives the following corroborations: the writer's accomplished and accurate friend, Mr. James Ferguson, Archt., F. R. S., who has carefully examined the pillar, is clearly of opinion that it is of forged iron. A fragment of it has been recently sent to England, and the writer is informed, on, he believes, good authority, that Dr. Percy has heated and drawn out upon the anvil a portion of it, and considers it to be forged iron. This test, probably all that so small a specimen admitted of, is not absolutely conclusive, as Dr. Percy himself would no doubt admit, for some cast irons, especially those made from hematites with charcoal fuel, admit of being heated and at once forged and drawn out hot into a sort of wrought iron. The photograph, as examined with the lens by the writer, presents to the practical eye several minute characteristics which incline him to believe it to be forged and not cast iron.

There will be seen clearly in the photograph—and also, though less so, in the engraving—the mark of the graze of a heavy round shot on one side, at about mid-height of the pillar; and so far as can be decided by examination of the photograph, the shaft is slightly cracked across, the widest part of the crack being at the side opposite to the graze mark. The blow, then, was just not enough to break completely the pillar by its own inertia, when thus suddenly bent beyond the limit of elasticity. Did we know the *vis viva* of the striking mass, and the density and exact dimensions of the pillar, it would be possible to calculate approximately the cohesion per square inch of the outside film of the shaft at this crack, assuming it really to exist; but wanting such data, and judging by tact or experience only, the writer is of opinion that if of British cast iron the pillar would have been broken completely off by the blow of a heavy shot.

The existence of a doubt as to the material of this pillar, one of the most marvellous metallic monuments in the world, shows with how little completeness it has yet been examined, and how entirely ignorant those who have described this pillar have been of the importance in elucidating the ancient working of iron in India of an exact metallurgical examination of its material. Let us hope this will forthwith be remedied—by cutting from the pillar (below the surface, it may be) and sending home a piece sufficiently large and long, not only for chemical investigation, but for experimental determination of its extensibility and cohesion per sq. in.; for physical and chemical examination together can alone determine with certainty whether it be of oriental cast iron or of wrought, *i. e.*, forged iron.

But meanwhile let us take the alternative suppositions, and see to what they will lead us. At the present day the prevalent belief is probably the correct one, that the production of or working in cast iron is unknown to native Indian workmen south of the Himalayas; and, unless made under European direction, a pig of cast iron of 100 lbs. weight could probably not be found in India. Yet how little is systematically known about the matter may be gathered from a recent notice ("Times," December 4, 1871) of some remarkable travels in 1868 in Central Asia by a native emissary of the Indian Government. "At Faizabad, the capital of Budukshan, a town a mile and-a-half in length and half-a-mile in breadth, along the banks of the Kokcha river, he found the inhabitants skilful in smelting iron, and they send cast-iron pots, pans, ornamental lamps, etc., to the market."

Assuming that in past time cast iron was known and worked in India, there is yet no reason to suppose that the furnaces in which it was melted could have been much larger than the little cupola furnaces, with blast from native bellows, which are now in use for making wrought iron direct. The very largest of these native furnaces appear to be those of Burmah ("Percy," p. 271, etc.), which by draught only produce about 90 lbs. of iron at each operation. It would have required between 300 and 400 such furnaces, working on cast iron, all got ready to tap and tapped at the same moment, to run a casting of 17 tons—an operation which any practical founder would admit to be impracticable with such apparatus, even in the hands of trained European workmen. Nor must it be imagined that the product of the existing little Indian cupolas, working on the direct process, is ever fluid enough to be tapped or run from the furnace. Were it so it might be conceivable that this pillar had been cast, and yet was of a crude wrought iron, or of a metal intermediate to cast and wrought iron.

Mr. R. W. Bingham, magistrate at Chynepore Shahabad, district of Bengal, in his report on iron-making, published in the official descriptive catalogue of the Indian articles exhibited in 1862 at London (4to, Calcutta, 1862), says as to that region of Bengal: "The metal never runs liquid from the furnace, but falls to the bottom below the blast pipe, from whence it is taken in a flaming mass by a pair of iron tongs, and which is hammered on a large stone, or on a rough iron anvil, into a double wedged-shaped pig," etc. This seems to describe the existing process of iron making of the present day, not only in Bengal, but all over British India, differing only in the size of the "bloom" or pig made, which is most commonly but 9 lbs. or 10 lbs., but in Burmah seems to reach its maximum size, viz., about 90 lbs., or rather less than one-third the weight of "bloom" produced in one operation by the existing Catalan furnaces in Europe, viz., about 140 kilogrammes ("Pelouze and Fremy," vol. iii., p. 228).

Are we then to conclude that this pillar was cast, in the absence of any evidence in support of that view—indeed, in face of whatever evidence we possess bearing on it—merely because we cannot conceive any other way in which it might have been made in India? If so, it follows, that between the fourth century, A. D., and the present day, the whole art of smelting iron in India has been changed, and that the indirect, or European method has been lost, and with it the knowledge of working in cast iron itself been also lost. Such a view is untenable, for vessels, or other objects of ancient cast iron, must, in that case, occasionally be found, which does not seem to be the case.

We are thus obliged to consider that this pillar is not a casting, but is a huge forging in native Indian or some other Asiatic-made wrought iron, and if so, the question arises, how was it forged? We have no evidence that "blooms" of more than 90 lbs. or 100 lbs. each, were ever made by Indian methods; these would be too small to build up singly into a bar of 16 in. diameter. It is, however, conceivable that such little "billets" as were procurable from such blooms might be welded up into bars, and these bars made into a faggot, out of which such a bar, by sufficient means for bringing it to a welding heat, and for then hammering it, might be welded into a cylindrical bar such as that of this iron pillar.

Now, the limit to the size of a faggot that can be welded with given means of *heating* it, is found to be when the mass is so great in proportion to the power of the furnace that the exterior of the mass, where the heat is being applied, oxidates and melts away, owing to the slowness of heating; and hence long continuance of exposure to the heat, as fast as piece after piece is laid on to make up for the waste. This limit has been reached before now even in our best reverberatory forge furnaces; it actually was touched upon at Liverpool, in forging the Mersey Company's great 13-in. gun. Unless, therefore, the iron-working of India between the 3d and 4th century, A.D., possessed air furnaces and lofty stalks, or blowing apparatus of some sort upon a scale now unknown, and indeed not conceivable in any form of native apparatus, we may confidently affirm that no faggot to form a welded bar of 16 in. in diameter could have been by any possibility brought to the welding heat at all, or without such waste as to prevent its ever being forged.

If we pass from the heating of such a bar to the forging of it, our difficulties are still greater. The limit in size of *hand-forged* work in Europe was about reached in the production, in days gone by, of the heaviest "best bower" anchor of a ship of the line. The largest section of the anchor shank, when welded to the arms, was about 8 in. or perhaps 9 in. across, and the welding was effected by the blows of 24 "strikers," trained to strike in time, and swinging 14 lb. to 18 lb. sledges. The shower of blows dealt for some minutes' spell, upon the mass of iron of this large section, produced a very insignificant effect, so that both the faggoting and the welding of such anchors were often very defective, and the strikers having to stand close in a ring, within the short distance for swinging the sledge from the glowing iron, were greatly scorched by its radiated heat, and some with fine skins were unfitted for the work. Hereabouts, then, the limit to hand-forging was reached, both as to the power of the hand sledge to act upon the mass of iron, and as respected the power of the men to endure the heat radiated from the glowing iron at the short distance from it limited by the length of the handle of a sledge when swinging. Now the section of the shank of a "best bower" of 8 in. or 9 in. diameter, is, to that of the Delhi iron pillar, about as 64 to 201, or the latter would radiate from its heated extremity more than thrice as much heat, and an equal length more than thrice as great a mass to be dealt with by the sledge hammer, as in the case of the anchor. We may, therefore, affirm that even in European hands a bar of wrought-iron of 16 in. diameter could not be welded up by hand labor with the sledge. The latter would produce no adequate impression—least of all in the comparatively feeble hands of Asiatics; and human skin and muscles could not withstand, at 5 ft. or 6 ft. off, the intolerable glare and scorching of such a mass heated to the welding point. How, then, was this Delhi pillar forged in India, even assuming that some means for heating it existed? Forging by power in some form, of course, suggests itself, but upon what source of power can we even speculate? Human muscles, and the "bullock walk" by which the water skins, or "bheesties," are drawn up from the wells or tanks, appear the only present sources of power in India. The water-wheel, or *noria*, for *raising* water by the application of such animal power, is common; but the production of power by the *descent* of water on a wheel seems never to have been known in India, where, indeed, except in the hill districts, no "falls" for water-power exist. The windmill, though said to have been known in Persia from some very remote period, has never been seen in India; and, it need scarcely be said, steam-power is out of the question.

It is barely imaginable that some form of falling tup hammer raised by men acting on ropes, after the manner of the old ringing engine for pile driving, may have been employed, or some rude form of tup or tilt hammer moved by bullocks acting on a walking wheel; and it is for Indian archæologists to discover if there be any records or traditions of such appliances, without which the methods by which this huge pillar was forged must remain inexplicable. The pillar itself stands before us, so far, a metallurgic enigma; if it stood alone, and were this great ancient forging in wrought-iron alone known to exist in India, we might pass it by, content to suppose it too isolated an instance on which to found any conclusions as to the iron metallurgy of that country in former ages; but, although little noticed, and apparently quite unknown to our European writers on iron metallurgy, this pillar does not stand alone.

Not to lay any stress on the probable existence in India of other iron pillars, as affirmed to the writer by an accurate Indian officer well acquainted with the country, the following facts are recorded by Mr. James Fergusson, in his "Illustrations of Ancient Architecture in Hindostan," fol., London, 1848, p. 28, and Plate III.

In the Temple of Kanaruc, or Black Pagoda, in the Madras Presidency, "the walls of the mantapa or porch (which is about 60 ft. square inside) are about 10 ft. in thickness, and the depth of the doorways is, consequently, 20 ft., and their lintels are supported by large iron beams of about 1 ft. section, laid across from side to side. The roof is formed after the usual bracket fashion of the Hindus, each course projecting beyond the other, so as to give (from the inside) the appearance of inverted stairs * * * * At about half the height, where its dimensions narrow to about 20 ft., a false roof has been thrown across, the remains of which now lie heaped up as they fell on the floor of the apartment. Among them may still be remarked several beams of wrought-iron about 21 ft. in length and 8 in. section, and a great many blocks of stone, 15 ft. and 16 ft. long (and they were probably broken in their fall), and of a section of 6 ft. by 2 ft. or 3 ft." Here then we have employed as mere building material wrought-iron bars of 8 in. square and 21 ft. long. Mr. Fergusson views this temple as having been built between A. D. 1236 and 1241.

In another temple examined and described by Mr. Fergusson—that of Mahavellipore, standing alone on a solitary rock of granite projecting into the very surf on the coast, near Madras—and the date of which he refers to the 10th or 11th century A. D., but deems may be as late as the 13th or 14th century, and described in his great work as above, p. 57, and Plate XVIII.—he informs me there are empty sockets for beams, like those just noticed; the beams, he justly argues, must have been of iron, as the sockets show a scantling, which would have been if in timber perfectly useless under the load carried.

It is highly probable that at Kanaruc the ceiling beams thrust themselves out of their sockets by alternate expansion and contraction, and so brought down the "false roof," as the filling above is called; but the place affords a bad foundation, and is said to be subject to earthquakes. However, our business with these iron beams is simply as metallurgic monuments. Here, then, we have the fact that at Delhi, in the north, and at Madras, in the far south of India, massive forgings exist, such as all Asia, so far as we know, could not produce at the present day, and of a size rivalling those upon which Europe to-day prides itself. The earliest of these dates from the 3d or 4th century, and the latest from the 11th to the 14th century of our era. With such an interval of time as 900 or 1,000 years, and such a diffusion in space as from north to south of India, it seems impossible not to conclude that the evidence of these monuments attests the existence in India for that long period of a great iron manufacture, well established, and with a relative cheapness and certainty of product that admitted of the use of iron as a material for public monuments and as a building material in sacred edifices, and that this manufacture was extinct, and the art and methods lost, long before any modern European occupation of India. So that far from Indian iron working having been the same feeble thing we see it to-day from time immemorial, it was once a great and flourishing craft, and extended over parts of the entire Indian peninsula.

Nothing heretofore brought to light in the history of metallurgy seems more striking, to the reason as well as the imagination, than this fact: that from the remote time when Hengist was ruling in Kent, and Cerdic landing to plunder our barbarous ancestors in Sussex, down to that of our Third Henry, while all Europe was in the worst darkness and confusion of the Middle Ages—when the largest and best forging producible in Christendom was an ax or a sword blade—these ancient peoples of India, the forerunners of those now so enfeebled and degraded, possessed a great iron manufacture, whose products Europe even half a century ago could not have equalled.

Yet, these conclusions rest on no new facts, but on the colligation of old ones, by the light of practical knowledge. Indian archæologists and writers have long known of the existence of these iron monuments of an ancient and lost art in India, but their importance has, the writer believes, not before been recognized as bearing on ancient Oriental metallurgy. The reason of this is that those who have examined the monuments of India, however scholarly and able in many ways, have not been metallurgists, and have had no practical knowledge of iron-working. The ancient, and, indeed, the existing technology at large of India—still more of Asia at large remains almost unexplored and undescribed, and whenever it shall be examined, analyzed, and described by really competent men—and such have never yet been commissioned with the task—results even more strange, and perhaps of more importance, historical and practical, than these deducible from the Delhi iron pillar, will, no doubt, come to light.

Since the foregoing was in type a notice has appeared in "Les Mondes" (tome xxvi., Dec. 1871), by M. Sévoz, an engineer of mines, resident in Japan, of the iron working districts of that country, which may throw some light on the conjectural modes by which these great forgings may have been effected by human power in those remote ages in India. In reference to the mode of iron-working in the mining province of Ykouno, M. Sévoz says, "The treatment employed is a sort of imperfect Catalan method * * * * but what distinguishes the Japanese method from that of (Depart.) Ariége is that they treat at once 16,000 kilos. of ore, and produce an enormously long pig of 1,300 kilos. which is broken up under a huge hammer, constructed after the style of a pile-driving ram, to which motion is given by a walking wheel of 11.5 metres diameter, acted upon (montée) by men. One can see that potent blows may thus be given, but their frequency and regularity do not seem such as thus to admit of a forging being produced, even if the means for heating a mass as huge as those referred to were capable of being guessed at.

THE WEIGHT OF RAILS.

By LOUIS NICKERSON.

From "The Railway Register."

A prevailing idea seems naturally to exist that great weight in a railroad bar is necessary to its economical wear. This is shown by the usual remark, when saving of the rail is noted—from the use of the Fairlie engine—in regard to the narrow gauge claims, or when steel is substituted for iron, "that it is better for economy's sake not to reduce the section, but rather to rely upon greater longevity than upon saving in first cost for gain." It may be true. But, after much thought on the subject, I have come to a totally different conclusion, and as each additional ounce of iron above the necessary quantity is so much money locked away from the use of companies, a discussion of the question which should prove that this, like all other natural phenomena, has its maximum and minimum points, cannot fail to be useful. Useful at any rate in drawing attention to the subject and thereby eliciting the truth.

The rail, unlike the other structural appurtenances of a railroad, has two separate uses, which call for two separate modes of treatment. First, in its character as a beam to convey the wheel from one cross tie to another. Secondly, its character as a road-bed to withstand the tearing and abrading influences, which result from the dragging of heavy loads over it. For the first case we have the general shearing stress, which from its depth may be disregarded, and the bending moment, which may easily be derived from calculation. Then, arranging the tranverse section so as to oppose the shearing stress, which tends to tear the side of the head along the line of the web, and otherwise place the iron in the best position for sustaining a known moving load, and moreover knowing the quality of the material exactly, the whole necessary size and weight as a beam may be deduced from formula, with a fair allowance for security.

But, beyond this, we must regard the rail in its capacity as a road surface, gather the facts and phenomena concerning its abrasion, and especially as regards its being torn into shreds and ribbons by some laminating cause, and inquire whether any additional mass of iron could be used to prevent it. It is evident that this laminating is governed by the amount of pressure brought to bear upon the upper surface, and we may first consider whether by an increase of material this surface could be made greater. It would seem not, for it having been already determined by experience that the cross section of the rail must have a curved upper surface; that the wheel must be circular; that the horizontal line of the track and the tread of the wheel must be approximate straight lines; and knowing that for an inflexible wheel upon an inflexible track the bearing surface could only be a mathematical point; and that the practical bearing surface can only be obtained by the yielding of material, we learn that to secure any benefit from an increase we must flatten the crown, so that we arrive at last at a greater detriment than the one sought to be avoided.

Years ago when we had only light engines and light rails, though the rail was lighter in proportion than the engine, there was only abrasion, and lamination was unknown. Now, the rail head is frequently rendered useless by lamination before the natural process of abrasion has commenced to reduce it. Rail makers have had their full share of blame for this, and doubtless in many cases with reason; but the best of iron rail, which when tried shows by no test a trace of scoria, graphite, or original lamination, coming from imperfect rolling, yields after being hammered for a time by the driver of the locomotive only a finer lamination than the cheap iron, which has still the divisions of the piling within it. Lamination is the result, then, of some natural and determined law, and that law is this: "That all material when subjected to pressure laminates in planes perpendicular to the direction of the pressure." From this it may be inferred, and indeed it is evident, that the amount of lamination increates with the amount of pressure.

Slaty cleavage, which is only lamination on a mountainous scale, early engaged the attention of geologists, and the opinion of Prof. Sedgwick, who pronounced it the result of molecular polar forces similar in action to crystalline aggregation and cleavage, was fully received. Scorby and others afterwards discussed the cause under other circumstances, and proved from and in regard to it, the law just given in this paper. Later, Prof. Tyndall took up the question. He produced lamination in clay and wax by pressure ; tried blocks of ice, and succeeding easily in obtaining lamination along the natural planes of freezing, turned his blocks around and laminated them by careful handling across these planes, thus proving the generality and power of the law. Some of the most interesting derivations and illustrations in his book on glaciers too, come from his use of this phenomenon. Housewives all know how dough laminates under the beating of the roller, when "Maryland or beat biscuits," and other bread of that kind is in process of making up, and maccaroni, which undergoes great pressure, at one stage of its manufacture, becomes leaf-like from it. Tyndall has mentioned all these save the last, and includes the scaling of railroad iron, but looking upon it in the mechanical idea of the running together of cells and imperfections, takes issue with Sedgwick and the early geologists. The writer sees no cause for issue, but regards crystalline and slaty cleavage and lamination as all proceeding from one anterior cause. That cause is this: That all force, whether in the form of light, or heat, or pressure, or otherwise, acts not continuously or by gradual diffusion, but periodically, or in waves.

All vitreous substances have a tendency, when under pressure, to split in cracks parallel to the direction of pressure. This is their received mode of destruction. In examining some crushed glass, the writer perceived that this recognized tendency was even in this substance modified by another tendency to divide into laminæ at right angles to these cracks. Some other facts being noted which showed a direct and close resemblance in their laws of destruction between glass, cast iron, and steel, he was induced to still further investigate by comparing glass beams and columns under different circumstances of pressure. It is well known that when glass is under strain, it becomes bi-refractive, and that in this condition it shows when polarized light is sent through it, the different conditions of strain into which its parts are thrown, both as regards quantity and circumstance, by the intensity, position, and direction of colored bands, shadows, and lines. It would be out of place in a paper like this to speak in detail of the brilliant exhibit of the colored curves of strain of the neutral lines, or rather the neutral spaces as they show themselves to be, or of the mysterious lines, which appear to be neutral in a peculiar sense, that occur amongst the colored curves. Suffice it to say, at present, that when any axis of pressure is traced its course is marked, not continuously nor by gradual diffusions and loss of intensity, but by periodically re-occurring phases. Indeed, the course of the experiments seemed to suggest that an object pressed by a weight derives no additional force from that weight, but that all bodies have within themselves the full quantum of force, necessary for their own destruction, which is only changed from an equilibriated condition to a polarized and effective state by co-ertion. Besides, if compression added destructive force to an object, then tensions should subtract from it, which is an absurd result.

In all cases of glass strained under polarized light, the different phases of strain are marked by different colored curved bands, always yellow, red and blue, transverse to the direction of the force, and the phases of neutrality by dark cloudy spaces. It is as if the original forces in the beam were a quiet crowd of beings, which, by the operation of the coercive force, were suddenly thrown into military line marching against each other from the top and bottom to engage in strife upon the common neutral space laying between them.

But it was possible to treat this law in a more practical manner, and the mysterious lines in the glass columns and beams, rendered meaning by mathematical analysis made this way clear; metallic tubes—as being easiest worked—were compressed carefully in the direction of the axis. The result was, as might have been prognosticated from the glass and from problems. The tubes already compressed in the testing machine of the St. Louis and Illinois Bridge Company were examined and gave the same result. That result was this: That they were wrinkled up transverse to their axis, in waves which were always for the same material a definite distance apart, agreeing with formulæ afterwards derived; the appearance being clearly that of a caterpillar or other uniformly jointed articulata. The formula is this,

$$a\left(\frac{r^2+1^2}{2}\right)^{\frac{1}{2}} =$$

distance from crest to crest of wave, the part under radical sign being general for all tubes, and (a) being a quantity dependent on the material. Several modifications and co-operative phenomena, which it is not necessary to mention here, were also obtained. The main object being to find whether a certain force of pressure being applied to the top of an object, it would be diffused generally through it, or whether it would have its periods of maximum and minimum strain. The latter was found to be the true law and its action to be, that the vertical pressure upon the extreme top became entirely horizontal at a certain distance below—at twice the distance vertical again—at three times horizontal again, and so on in accordance with the above description of physical effect and the formulæ—which latter was further developed by finding for steel, $a = \frac{1}{3}$, for brass, $a = 5\text{-}6$; the theoretic a, being equal to unity. Softer metals, copper, tin and lead, were also also tried, but with as yet unsatisfactory results, as might be expected. The nature of the colored bands and clouds was thus fully developed. They were phases along the lines of force upon which changes of character took place. The colors themselves, too, are best explained on the supposition, that all the active portions of a beam or column under coertion is made up of minutely narrow spaces of strain alternating with minutely narrow spaces of neutrality, both parallel with the curvature of bands, and consequently perpendicular to the direction of the coertion. This would be another cause for lamination.

Looking then upon a railroad bar as it rests from tie to tie, we can regard it as a beam similarly circumstanced to a similar transparent beam, with the same continuous bearing. This case was also tried in glass, and with the same phenomena, and the writer has no reluctance to assume from the results of the experiments that when the wheel or other weight presses upon the rail, or other object, that a vertical section marks periodic phases succeeding each other similarly to those so plain in the more obdurate material, glass, and that along certain re-occurring lines the tendency to divide and separate is much greater than along any intermediate lines. The plane of separation being of course the neutral planes in preference to planes of direct strain, because the force there acts in opposite directions along each side of the plane. It may be remarked that if glass which generally shows a totally opposite system of yielding, can thus prove our law, the effect must be greatly increased in wrought iron, which structurally characteristically yields in the lammalae direction.

Before proceeding further in respect to the nature of the injury received by the rail, it is well that we should examine the character and quantity of the cause producing the result. Our ordinary locomotive weighs usually about 30 tons. Of this, $\frac{2}{3}$ rests upon the driving wheels, and $\frac{1}{3}$ is lost for adhesion upon the truck. When at rest, then, there is a normal weight of 5 tons for each of the 4 drivers, and $2\frac{1}{2}$ tons for each of the 4 truck wheels. From this cause the engine, as a whole, is unbalanced; a detriment which shows itself in all locomotives constructed with this view of increasing the weight on the drivers for the purpose of adhesion, by causing in rapid motion a galloping and hammering action upon the rail. Mr. Fairlie made some experiments in England, upon engines having a similar arrangement of weights, and states the result as an increase of 4 tons additional thrown upon 1 driver or the other, as the weight shifted in running; thus changing the normal 5 tons weight to 9 tons blow. He also states that a 7-ton wheel will hammer to the extent of 12 tons. As Mr. Fairlie is the inventor of an engine which mainly obviates this defect, I will draw closer attention to the more than corroborative experiments of Baron Von Weber ("Chicago Gazette," February, 1871), from which is deduced an increase of 103 per cent., thus increasing the normal 5 tons to 10 $\frac{15}{100}$ tons. This would appear to be a very sufficient cause when brought upon a space on the top of the rail, probably less than $\frac{1}{2}$ of a sq. in. in area, to achieve any damage of which iron or steel was susceptible.

Starting afresh, then, from our last sentences, and admitting that from the previous reasoning we may accept lamination as caused by a general law, modified by, frequently, but not dependent upon, bad manufacture, it may be asked could any addition of material in the rail, not increasing the bearing or rolling surface, lessen the damage? For myself, I think not. Nay, I think the damage would increase with the additional mass. It is frequently remarked, as an anomaly upon roads where light iron alternates in sections with heavy, and is therefore run over by the same trains, that the heavy iron wears the most; that iron rail is most apt to wear upon, or at the edges of, the ties than between them; more in rock cuts than in softer foundations. And almost all railroad men have heard the legend of the Boston and Worcester or some other road, where, for the greater perfection of running and gain in economy, the rails were laid upon granite sills, and how the rails and machinery were so beaten up in a short time that the sills had to be dispensed with, and a more yielding substructure substituted. But the Boston and Worcester road was but an item in the long account; almost every railroad man can recollect some instances which, coming under his own observation, have proved to him that rigidity was imperfection.

Come to a more simple and homely trial: place a piece of iron upon an anvil, and strike it with a hammer; the effect of the blow will result from the momentum of the hammer—and the resistance of the anvil. Should the anvil drop as fast as the hammer, there would be no impinging effect; half as fast would result in half the effect; perfect rigidity would give a full effect. Our question, then, narrows down to this: "In what degree does the body of the rail act as an anvil to its own crown, and in how much, if at all, would increasing the mass, and consequent rigidity, add to the anvil-like effect?" Much, it would appear, and more than that: by decreasing the bending of the rail as a beam beyond what may be necessary to preserve its integrity, we but reduce so much of the surface of bearing as has been gained by that yielding.

This is a practical question, and must be answered by experience; and not the experience of one, but the combined knowledge of many. Will not some of those gentlemen, whose track bears us safely across thousands of miles of country—a result necessarily obtained only by great exertion, ability, thought and patience—give some portion of these qualities to the solution of this problem? For in whatever direction the result should turn, its great pecuniary value makes it worthy of attention.

ABSORPTION OF MOISTURE BY BRICK AND STONE.

By JOHN C. DRAPER,

Professor of Chemistry, University Medical College, New York.

From "The American Railway Times."

In the construction of buildings in a climate like ours, it is of the utmost importance that the materials employed should absorb and retain as little water as possible, otherwise the buildings will be damp, and the presence of quantities of moisture in their walls will favor the formation of vegetable growths upon their surfaces, which will, together with the action of frost, aid materially in the process of disintegration.

In a recent investigation of this subject, I selected the following materials, namely, brown stone and Nova Scotia stone of the best quality, fine red Philadelphia brick, and a very compact, hard burned white brick, stamped A. Hall & Sons, Perth Amboy, N. J. Masses of equal size of each were placed in water for twenty hours to allow them to imbibe as much of the fluid as they could take up. They were then turned about on blotting paper as long as they dampened it. The external moisture being thus removed, the masses were weighed, and placed in an air bath at 212 deg. for 3 hours. On being removed from the bath, they were put under a glass bell jar, and being again weighed when cool, were found to have lost the following quantities of moisture:

TABLE I.

Brown stone,	10,000 parts.	lost	260	of moisture.
Nova Scotia stone,	"	"	260	"
Red brick,	"	"	1,179	"
White brick,	"	"	525	"

The masses were then placed in the warm air bath again, and kept at 212 deg. for 4 hours. On being cooled with the same precautions as before, they showed the following losses:

TABLE II.

Brown stone,	10,000 parts,	lost	8	of moisture.
Nova Scotia stone,	"	"	8	"
Red brick,	"	"	0	"
White brick,	"	"	0	"

The masses were then placed on an iron plate, which was heated to a dull red heat, and covered with a hood of tin to cut off currents of air. They were consequently exposed to a uniform temperature, which was sufficiently high to scorch paper when it was laid on their upper surfaces. The last traces of water were thus expelled, the quantities being as follows:

TABLE III.

Brown stone,	10,000 parts,	lost	17	of moisture.
Nova Scotia stone,	"	"	35	"
Red brick,	"	"	a trace	"
White brick,	"	"	a trace	"

The conditions to which the substances were submitted at the commencement of these experiments on drying, may be regarded as representing their state after a prolonged storm of rain in which they had been drenched and soaked with water for many hours, and Table I. demonstrates that while the brick absorbed more moisture than the stone, the white brick imbibed less than half that taken up by the Nova Scotia stone.

Table II. in its turn shows that stone is far more retentive of its moisture than brick, for, while the former lost 8 parts, the latter lost none. In Table III. the same fact is still more conclusively demonstrated, for against an almost imperceptible loss on the part of the brick, the brown stone lost 17 parts, and the Nova stone 35. We are therefore justified in concluding that though brick absorbs a larger quantity of moisture than stone, it is to be preferred as a building material, since it parts with the imbibed water with greater facility; and, comparing the two kinds of brick together, the white hard burned brick is superior to the red, since it absorbs only half as much water.

Passing from the consideration of the power of retention to that of absorption, I found that, on submitting the thoroughly dried masses of the last detailed ex-experiment to the action of an atmosphere saturated with moisture at 70 deg. Fahr. for 6 days, the following results were obtained:

TABLE IV.

Brown stone,	10,000 pts.	absorb	at 70 deg.	52	of moist're.
N. S. stone,	"	"	"	45	"
Red brick,	"	"	"	3	"
White brick,	"	"	"	3	"

The conditions prevailing in this experiment may be regarded as similar to those existing on an ordinary midsummer day when the dew point stands at 70 deg.; and on inspecting the table we find that, while the brick absorbs but little moisture, the stone is very hygroscopic, the brown stone possessing this property in a more marked degree than the Nova Scotia. Since warmth and moisture, taken together, are peculiarly favorable to the production of vegetable growths, it follows that brown stone is, by virtue of the larger amount of water it absorbs, more liable to disintegration from this cause than the other substances submitted to the experiment. In the case of the bricks the absorptive power is, as the table shows, equal, and very slight or slow in its action. They are, therefore, superior to stone in this respect.

To determine the absorptive power when exposed to conditions similar to those prevailing during a fog, I caused steam from a free opening to play upon them for 3 hours. After cooling for 20 hours they were weighed, with the following result:

TABLE V.

Brown stone,	10,000 pts.	absorbed	147	of moisture.
N. S stone,	"	"	"	110	"
Red brick,	"	"	"	127	"
White brick,	"	"	"	106	"

Which demonstrates that under such circumstances brown stone is more hygroscopic than Nova Scotia stone, and, therefore, affords a more favorable *nidus* for vegetable growths, and is consequently less durable. In the case of the bricks, though the red brick absorbs more fog than the Nova Scotia stone, it is a better building material, since it surrenders its moisture with greater facility. The white brick, on the contrary, absorbs less fog than the others, and dries as easily as the red brick; it is, therefore, the most satisfactory of the building materials submitted to examination.

RUSSIAN PROGRESS IN ASIA.—The Russians appear to consider that by the conquest of Turkestan they have gained a second India, and to be earnestly bent upon improving the natural resources of the new province. The chief improvement on which they pin their hopes is extensive irrigation, by means of which they expect to raise large crops of silk and cotton. A project for irrigating the steppe of Dzizak is at present under consideration, several engineers having been employed by Government in surveying the plain and working out a plan, which, if approved, will be put into operation at once.

THE TEHUANTEPEC RAILWAY AND SHIP CANAL.*

LONDON, *October* 16, 1871.

SIMON STEVENS, Esq.,

President of the Tehuantepec Railway Company, New York.

SIR,—The undersigned, appointed by you, a Commission to examine some of the principal artificial waterways in Europe, with a view of applying the best and most recent experience to the project for an interoceanic railway and ship canal across the Isthmus of Tehuantepec, Mexico, respectfully report, that a portion of our number have examined personally the Caledonian Canal, the great Dutch Ship Canal now under construction for the purpose of establishing an easy and direct communication between the port of Amsterdam and the German Ocean, and also the less known, though very interesting, work now in progress at the Hook of Holland, viz., the new Waterway from Rotterdam to the Sea ("Waterweg van Rotterdam naar Zee").

The members of the Commission have been courteously furnished with every facility for the examination of these interesting works. The Lord Advocate of Scotland, one of Her Majesty's Commissioners of the Caledonian Canal, kindly furnished us with letters to the officers in charge of the canal; the superintendent of which, Mr. Davidson, accompanied us, and explained the more interesting parts of the works. To the eminent engineer, Mr. Hawkshaw, and to his associate at Amsterdam, Mr. J. Dirks, we are indebted for the fullest information, together with plans of the Amsterdam Ship Canal, one of the most remarkable works of engineering of the present day. Mr. Dirks personally accompanied us in our examinations. To Mr. Caland, the chief engineer, and a member of the "Waterstaat" of Holland, we are also indebted for the opportunity of making ourselves personally acquainted with the work at the Hook of Holland, as well as for documents and valuable information.

Want of time (owing to duties or engagements) has prevented personal visits to other great waterways, especially the Suez and Languedoc Canals, which would be instructive in reference to a project for any new ship canal; but these works are so thoroughly described, their characteristics and details so well known, as to enable us to dispense with personal examinations. The various surveys and projects for ship canals at sundry points across the American isthmus, are of course familiar to, and have been attentively examined by us.

A brief memoir of the history of the railway and canal project for the Isthmus of Tehuantepec will be in place here. This isthmus has always, since the early days of American discovery, attracted attention and explorations, as one of the most available points for interoceanic communication; but the project for a "ship canal" first assumed a definite form in the Report† by Señor Moro, founded on a survey made in 1842.

This survey originated in the concession by the Mexican Government to Don José de Garay of the right to open a communication between the Pacific and Atlantic Oceans, through the Isthmus of Tehuantepec, coupled with the condition that the grantee "shall cause to be made at his own expense a survey of the ground and direction which the route should follow, and also of the ports which may be deemed most proper and commodious from their proximity."

Although the communication to be established was not necessarily to be a ship canal, or even (wholly) a water communication, yet it is evident that such a canal, or at least a great canal, was contemplated both by the Mexican Government and the grantee; and the engineer, Moro, expressly states that to such a communication his attention was chiefly directed in making his survey.

In fulfilment of the obligation to make a survey, Señor de Garay immediately dispatched to the Isthmus a Scientific Commission, composed of Señor Gaetano Moro as chief, and Lieut.-Col. de Trouplinière, and Capt. Gonzales, of the staff corps, and Lieut. Mauro Guido, of the navy, as assistants, and Don Pedro de Garay, an

* From the Report of the Commission on the Artificial Waterways of Europe.

† "An Account of the Isthmus of Tehuantepec, with proposals for establishing a communication between the Atlantic and Pacific Oceans, based upon the Surveys and Reports of a Scientific Commission appointed by Don José de Garay. London, 1846."

officer of the Ministry of War, as secretary. The Commission spent 9 months upon the Isthmus in the execution of its task. It fixed the position of the more remarkable points by astronomical observations or by triangulation, measured the most important altitudes by barometric or trigonometric observations, and explored in a general way the more important watercourses and harbors ; and furnished, so far as it went, a tolerably accurate account of the Isthmus in its geographical and topographical relation to the question of a canal, and gave very valuable information concerning the mineral wealth, and the natural and agricultural productions.

Señor Moro based upon this survey a project for a canal 20 ft. in depth, and 50 miles in length, connecting the upper waters of the Goatzacoalcos, on the Gulf side, with the lagoons of the Pacific coast. The summit was at Tarifa, at about 680 ft. above the level of the sea.

Further than to make the survey mentioned, nothing was accomplished by Señor de Garay with regard to executing the canal. After the acquisition of California by the United States, this route acquired a new importance as a means of communication with our newly acquired Pacific territory. Could possession have been obtained at once, Tehuantepec would probably have become the established route of communication, owing to the great saving of distance over Panama, as well as the salubrity of the climate.

Soon after the close of the war between Mexico and the United States, the franchises and privileges of Señor de Garay, became the property of Mr. P. A. Hargous, of New York, who in connection with a company formed in New Orleans, assumed the rights and responsibilities of the Garay-grant. But the necessary negotiations with the Mexican Government, and with other parties interested, delayed a commencement of operations till December, 1850, at which time the Company having applied to President Taylor for an officer of engineers to direct the survey, Brevet-Major J. G. Barnard, Captain of Engineers, was detailed for that purpose. The aspect of the problem was at this period peculiar, the great object being to establish at the earliest possible day an available route for the great flood of travel between our Atlantic and Pacific coasts. Hence the idea of a canal was put aside, and that of a railroad substituted. The survey then ordered was therefore organized and executed solely in reference to a railway and a preliminary and auxiliary wagon road, and these it was urgent to establish with the least possible delay. These facts not only shaped the whole character of the survey, but they even altered the route. It was necessary to extend these roads at once to the Pacific (instead of striking the lagoons as the canal would do); and the "Ventosa," or "Salina Cruz," were the most available points for the Pacific terminus.

Instead of passing over Moro's summit (Tarifa), the more westward passes of Chivela and Masahua were surveyed. Hence the survey under Major Barnard not only did not coincide with Sr. Moro's at the summit, but the entire route between the seas was quite different from that which a canal would occupy. The survey thus executed may be said to have been commenced in the end of December, 1850, and substantially terminated early in the following June (1851). Its results are so fully set forth in the Report of the Survey, prepared by J. J. Williams, one of the undersigned, that we need only state that it established the practicability of a railway route at moderate expense, and with grades not exceeding 60 ft. per mile, and with a summit about 800 ft. above the level of the sea. The passes surveyed were not supposed to be as low as the more eastern one of Tarifa, and no observations whatever were made, specially directed to the practicability of a canal.

In the year 1857 the railway project was resumed and a new survey executed under the direction of W. H. Sidell, now Lieut.-Col. of Infantry and Brevet Brigadier General, U. S. Army, a distinguished civil and railway engineer, the object being a final location of the road. This latter survey was made with much care and expense. Upon its results and the previous surveys the line of location has been definitely laid down, the cost of construction estimated, and everything established necessary to the issuing of specifications for contracts for the execution of the work.

Since the revival, under the impulse of the successful execution of the Suez Canal, of interoceanic canal projects, the claims of the Isthmus of Tehuantepec for favorable consideration have gradually acquired a pre-eminence which was at first denied.

The virtual failure of all the recent explorations instituted by the United States Government to find a practicable route where the Isthmus is narrow—as at Panama and Darien—and the superior advantage of geographical position of Tehuantepec, its healthfulness, and its vast local resources for the construction of such a work, and its established practicability, in an engineering point of view, for a canal with locks, are now understood, and must have their weight.

In describing the different surveys that have been made, we have reserved mention of the most recent; and in reference to the establishment of the "practicability" which we have claimed for the canal project, the most important. We allude to the survey made during the last winter and spring by Captain R. W. Shufeldt, of the United States Navy, by order of the President of the United States, in pursuance of an Act of Congress for that purpose, and with the co-operation of the Mexican Government, for the special object of determining the question of an adequate water supply.

The final report had not been transmitted to the Navy Department at the date of our leaving the United States, but the authenticated copies of preliminary reports have been furnished you by the Hon. Secretary of the Navy, and are given in full in the appendix of this Report.

We have in them, from the highest source and in the most positive form, the important conclusion, "that an interoceanic canal of any necessary dimensions may be constructed across the Isthmus of Tehuantepec." We have also the further statement of the engineer on whose exploration Captain Shufeldt bases his own dictum (just quoted), "that a ship canal across the Isthmus of Tehuantepec is not only practicable, but also that the topography of the country presents no extraordinary obstacles to its construction."

The latter statement that "the topography of the country presents no extraordinary obstacles to the construction of a canal," is but a confirmation of the information obtained from Major Barnard's, Mr. Sidell's, and Señor Moro's surveys. The railway surveys and location passing over a line nowhere actually coinciding with the probable line of location of a canal, does not of course furnish the means of exhibiting a profile of such a location; but most of the country through which it would lie has been traversed by Major Barnard's, Mr. Sidell's, Mr. Williams', or Moro's parties. Moreover, it should be borne in mind, unlike the country over which explorations have been recently carried across the Darien Isthmus, through wildernesses entirely unknown to civilized man, of which a single line of survey will furnish but very meagre information, the Isthmus of Tehuantepec has been a thoroughfare for centuries, while for the last 30 years surveying parties have been, at intervals, traversing it from shore to shore, either with instruments of precision in their hands, or subjecting it to scientific reconnaissances. With these preliminary remarks, we will proceed to define the probable line of location for a canal, commencing at the summit.

The summit determined in 1852 by Señor Moro was near Tarifa. This selection was confirmed by incidental examination during Major Barnard's and Mr. Sidell's surveys,* and has now been once more confirmed by the survey of Captain Shufeldt. This summit level was barometrically determined by Señor Moro as being 680 ft. (206 metres) above the level of the sea. The precise determinations of the elevation of the contiguous (railway) summits of Masahua and Chivela authorize the belief that the above statement of Moro is near the truth. The descent towards the Pacific plains (elevated at the foot of the mountains about 240 ft. above the sea) would be either by the "Portillo de Tarifa," or penetrating the small "Cerro del Convento" by the valley of the Monetza to its junction with the Chicapa, and thence by the valley of the latter river. The latter route furnishes the greater development (say 10 or 15 miles) for reaching the plains. Either route is believed to offer no extraordinary difficulties, though doubtless this descent is the most formidable work of the project. No tunnel is necessary, and

* "As Principal Engineer of the Commission under Major Barnard, while making explorations and a survey for a railroad across the Isthmus in 1851, I took occasion to examine the dividing ridge over which Moro had made his surveys for a ship canal in 1842; and although I did not pass over the entire route as surveyed by Moro for a ship canal, still I was at Tarifa, the summit, and on the most difficult ground over which he proposed to construct it, and I think I am safe in pronouncing the route, as surveyed by him, the most practicable of any yet explored."—*Report of J. J. Williams*, 1870.

It is also worthy of remark that in the report of Major Barnard's survey the "Rio del Corte" was indicated by the same engineer as a probable source of adequate water supply for the summit level of a ship canal. See page 245 of his Report.

the difficulties will lie in locating the bed and locks of a great canal along a descending mountain pass, in which the necessary excavations must be mostly in rock.

From Tarifa to the Portillo or to the Cerro del Convento, the distance is about 4 miles, measured over a plain so level that in the rainy season it becomes inundated. To depress the summit below the level of this plain would require a deep cutting extending several miles. Such a cutting, even to the depth of 100 ft., in relation to the magnitude and importance of the work, of which it would form an inconsiderable part, would hardly be thought formidable ; and the resulting advantage of reducing the number of locks, and placing the summit more conveniently in reference to its supply of water, may quite probably demand it.

We shall therefore assume that the canal summit is not over 600 ft. above the sea. The descent to the plains at the foot of the mountain would therefore be 360 ft., requiring 36 locks of 10 ft. lift. From the foot of the mountains the canal, descending through 240 ft. with the natural slope of the plains, would reach the Upper Lagoon in a distance of about 14 or 15 miles.

The main source of water supply of the summit, as determined by the survey of Captain Shufeldt, will be from the upper waters of the Rio del Corte, at a point some 25 to 30 miles from Tarifa. The route of a feeder was carefully surveyed, with transit and level, by Mr. Fuertes, chief civil engineer under Captain Shufeldt, who found it entirely practicable. Mr. Fuertes finds the supply furnished by the Rio del Corte, and other available sources, at its lowest stage, to be 2,000 cubic ft. per sec., or 120,000 cubic ft. per min.

From the summit towards the Gulf of Mexico, the canal would follow the well-defined route of the valley of the Tarifa and Chichihua rivers, to the junction of the latter with the Malatengo. Crossing the latter stream, it would strike the Goatzacoalcos at Old Mal Paso, which river it would cross at that point.

The route from Tarifa to the Malatengo and Goatzacoalcos is thus described by Señor Moro :—" This part of the country is the most fertile and pleasant that it is possible to imagine. Shortly after leaving Tarifa, it is truly interesting to observe, mixed together, the spruce and fir-tree of the cold climates, the oak of the more temperate, and the palm-tree of the warm regions. Further on, these trees, as well as beautiful green meadows of vast extent, occur alternately, with woods of a luxuriant tropical vegetation. Trees of precious woods, wild cacáo, vanilla, etc., are everywhere seen. The plains near the rivers, cultivated by the inhabitants of El Barrio, Santa Maria Petapa, and San Juan Guichicovi, give an idea of the astonishing fertility of the soil, since the natives only come in time to burn down the brushwood, and sow without cultivation, scarcely ever revisiting their corn-fields until the harvest time."

Various considerations caused the left bank of the Goatzacoalcos to be preferred for the railway surveys ; but there is no doubt that the proper location of the canal is on the right bank. A diminution of length by some 40 miles, the avoidance of transverse ridges (easily surmounted by a railway), the fewer crossings of streams, and the avoiding of the overflows—all are considerations uniting in its favor.

From the Lagoons to the summit at Tarifa, and from that point to the crossing of the Goatzacoalcos, the line is so well defined as to leave but the mere details to be determined. From that point the canal, to avoid the great Suchil bend of the river to the westward, would follow, as near as practicable, its chord, crossing the Chicolote and the Chalchijapa, and approaching the Goatzacoalcos again near the source of the Coahuapa. This region is a dense forest. Observations taken from the summit of Mount Encantada, authorize the belief that it is unbroken by any great topographical irregularities. The only considerable streams to be crossed (this statement applies to the whole route) are the Malatengo, the Goatzacoalcos, the Chicolote, and the Chalchijapa. The second named is by far the largest. The ordinary rise and fall is 17 or 18 ft ; but in exceptional seasons it is stated to have risen higher. The point of proposed crossing has been selected on a thorough knowledge of its favorable character.

From the Coahuapa to the junction and termination in the Goatzacoalcos River, the proposed route lies through a country nearly level.

The entire length of purely artificial canal thus approximately located, will be from about 115 to 120 miles. The number of locks would be 120 in all, assuming a summit of 600 ft., a lift of 10 ft., and also, as we have a right to do, that there will be no secondary summits.

We have now to speak of the harbors. The Goatzacoalcos, for 30 miles from the Gulf of Mexico, forms an excellent harbor. Its access is over a bar having 13 ft. at low water (according to the recent survey of Captain Shufeldt).* This bar is unchanging, and we anticipate no serious difficulties in attaining a navigable depth of 20 ft. or upwards. From the bar up to the point where the canal (as we have described its location) terminates, a distance of about 30 miles, the river is generally over 20 ft. deep. At a few points there are but 15 or 16 ft. depth. Of course, to adapt this portion of the river to a ship canal, will require channel improvements, and perhaps some rectifications in its course—no work, however, of great magnitude.

On the Pacific, the Upper Lagoon furnishes a basin in which, in the region occupied by the islands, and thence to the canal Santa Teresa, a depth of water of about 20 ft., with a mud and shingle bottom, is found.

To reach the ocean, one or both of the narrow peninsulas, which separate the lagoons from it, must be cut through, and an external harbor, or entrance piers, thrown out similar to those now under construction at the North Sea terminus of the Amsterdam Canal. The works at Suez, those at Amsterdam, and those of a very different character at the mouth of the Maas, yet having much in common with them, and with that which we are now proposing, are sufficient proof that, to modern engineering, the establishing of a good entrance to these lagoons, for vessels of large draught, is quite practicable.

In the railway surveys it was important to reach the best existing port on the Pacific. Ventosa was first selected. Neither this point nor Salina Cruz is considered eligible for the canal, owing to the advantages the lagoons offer for a capacious harbor, and the diminution in length of artificial canal and avoidance of river crossings; but it is interesting to know that there are already secure anchorages in the close vicinity of our proposed entrance to the canal.

The statements given in former reports* show that the formation of an external harbor on the Pacific coast, which will afford entrance to the lagoons, is fraught with no probable difficulties, and that the coast is not a dangerous one, and that there now exist in the close vicinity safe anchorages.

It would be quite premature to attempt an estimate for the work we indicate. Surveys of the line can alone determine the data upon which one can be made. But we state with confidence that, for the length of the line and height of summit, it is rare to find a route so devoid of engineering difficulties. Moreover, the isthmus furnishes every variety of building material, while from its population, and that of the States of Oaxaca and Vera Cruz, can be drawn, at no expense for transportation, a hardy laboring force quite adequate to execute the work. The soil of the isthmus and of the contiguous regions, affords in abundance sustenance for such a force. The climate throughout is healthy even to European laborers. With a native force sickness is not to be anticipated. Hence, some of the most formidable difficulties and sources of expenditure in the construction of interoceanic routes, at other more southern points of the American isthmus, are not encountered on the Isthmus of Tehuantepec. The cost of earth and rock excavation or masonry, should not exceed, on the Isthmus, the cost of similar works in Europe.

In this connection we express our hearty concurrence with the views of M. Thomé de Gamond, in his "Avant projet," for the Nicaragua canal, projected by M. Felix Belly. M. de Gamond says: "We think that, after the example of the Dutch and the Americans, it is important to make extensive use of timber instead of masonry. The San Juan river traverses a virgin forest, furnishing trees of great dimensions, both in diameter and height. These timbers belong to the 'Concession,' and

* The survey of Lieut. Leigh, U. S. Navy, in 1848, gave 12½ ft. *at extreme low water of Spring tides.* There has probably been slight if any change.

* Barnard's Survey.

can be employed in unlimited quantity, with no other expense than that of the carpenter's work. To overlook the value of these gratuitous resources, and to prefer masonry merely because masonry is more durable and more monumental, would be to increase expense for an empty satisfaction."

Again he says: "It would be an error to think that we can, in this enterprise, copy works executed in Europe under the formal rules of construction there adhered to. It is necessary, above all things, for the accomplishment of such an enterprise, to lay under contribution the immense local resources of nature, and to utilize in the employment of these resources that which is most applicable in the distinctive genius of every nation."

All that is said above by M. de Gamond applies perfectly to Tehuantepec. The immense forests of the most valuable and durable timbers which lie along the route should furnish the material for locks, bridges, and aqueducts, by which the expense of these otherwise most costly structures will be reduced to a fraction of that which masonry would require.

The use of timber in the United States for locks and aqueducts and bridges is so common that we need not refer to examples: to adopt its use at Tehuantepec is but to adopt the principle of M. de Gamond, and to apply the "distinctive genius" of American construction to an American work, and at the same time to "utilize" the immense constructive resources offered us in the forests of Tehuantepec.

In what precedes we have given no "dimensions" for the proposed canal. It would be premature in this report to do so. But it should be understood that we refer to a SHIP-CANAL, with an availabe depth of not less than 20 ft., and locks of corresponding dimensions (say of 450 ft. in length and 50 ft. in breadth). The present transition state of ocean navigation, in which a substitution of steam for sails, and of steam vessels of enormous length for existing models, furnishes an independent and adequate motive for the use of timber for locks. While it would be imprudent to hamper navigation by "monumental" constructions of dimensions which might prove inadequate to the future, it would certainly be premature to build, in masonry, locks of the enormous length that some shipbuilders anticipate iron steamships are destined to attain.

We have but to add that the proposed railway, owing to local resources, and the extent of rich and productive countries which would come tributary to it, would command a lucrative traffic independent of interoceanic movements, and would be almost an indispensable auxiliary in the construction of a canal, in which capacity alone it would pay for its own construction.

We are, Sir,

Respectfully, your obedient Servants,

J. G. BARNARD,
Colonel of Engineers, Bvt. Major General, U. S. Army.

J. J. WILLIAMS,
Chief Engineer, Tehuantepec Railway Co.

JULIUS W. ADAMS,
Engineer Public Works, City of Brooklyn.

THE POROSITY OF CAST IRON.

From "The Mechanics' Magazine."

The crystalline structure of cast-iron renders it peculiarly susceptible to leakage by the passage of liquids and gases through its substance. The former require pressure to force them through the body of the cast iron, while the latter are assisted by heat. A familiar example of the passage of water through cast iron is that of the hydraulic press. In some cases this leakage is very severe, and diminishes the working power of the apparatus in a very large degree. Of course the castings for these presses require to be run in a special manner, and the iron used should be of as fine a grain as possible. They should be cast with a good head of metal, and, where possible, under pressure. In cylinders of large size, and consequently of great thickness, the run of metal should be continued after the proper quantity has apparently been admitted into the mould. The metal should, moreover, be pressed or rammed into the mould, so as to render the casting as sound and close as possible throughout, by supplying the contraction in cooling. Without these precautions, and often with them, the iron will sometimes prove faulty near the waste head of metal. This was the case with the first cylinder cast for the large presses used in raising the Britannia tubular bridge. The internal diameter was 1 ft. 10 in., the diameter of the ram being 20 in.; the cylinder was 6 in. thick, its external length being 9 ft. 1½ in., and the length of the stroke 6 ft. The weight of the finished press was 13 tons 16 cwt.; but, on account of the great head of metal requisite in such castings, 21 tons of iron were run into the mould.

The first cylinder was cast bottom upwards, and, notwithstanding that every precaution was taken to feed the mould for many hours, it proved faulty. The cylinder was turned and finished externally and internally, but, on cutting off the waste head of metal at the bottom of the press, a spongy hollow space was found in the centre of the metal capable of containing upwards of a pint of water. This cylinder was consequently rejected, and the next one was cast with the bottom downwards in its natural position. By this means the most sold metal consequently occurred at the bottom of the press, and the more porous metal at the top. To condense this as much as possible, a head of nearly 7 tons weight was run on the top and afterwards cut off; the metal was fed to the mould for 6 hours after the casting. But with all these precautions the press proved to be leaky at the top. The remedies prescribed by Mr. Edwin Clark consisted in adding a second leather collar beneath the original one, in hammering the cylinder, and in forcing into the pores of the metal a thick gruel made of oatmeal and sal-ammoniac. The filmy particles of the oatmeal were thus mechanically fixed in the pores by the corrosion produced by the sal-ammoniac. Instances have occurred in practice when hydraulic cylinders of great size have been made of wrought iron with external rings of the same metal shrunk on them. These of course come expensive, and as cast-iron, from its very nature, will leak under pressure, the best thing appears to be to dose it well with Edwin Clark's gruel.

The passage of gases through the pores of cast iron, to which we have referred, is quite another matter, and refers principally to close stoves made of that metal. The question involved here is one of great scientific interest, and is important in a sanitary point of view. We are most of us familiar with the unpleasant condition of the atmosphere in a room heated by a close stove. It was, however, on the continent—where this method of heating apartments is extensively adopted—that the practical bearing of the question was first discussed, and we are indebted to Dr. Carret, one of the physicians to the Hotel Dieu in Chambery, for originally bringing it under notice. That gentleman, a few years since, drew the attention of the Academy of Sciences to the subject in a series of papers, in which he dealt with the evil consequences of the use of cast-iron stoves. Little interest, however, was excited in the matter at the time, but General Morin subsequently brought the matter forward with better success. Dr. Carret plainly denounces cast-iron stoves as an absolute source of danger to those who use them, and he bases his denunciations upon the following somewhat conclusive facts:—During an epidemic which prevailed in Savoy, Dr. Carret observed that all the inhabitants who were affected by it used cast-iron stoves which had recently been imported into the country. On the other hand he observed that all those who used other kinds of stoves or adopted other modes of firing escaped the disease. Another circumstance bearing on the same question occurred in the Lyceum of Chambery, where an epidemic of typhoid fever broke out. This outbreak is regarded by Dr. Carret as being influenced by a large cast-iron stove in the dormitory of that establishment.

General Morin endorsed Dr. Carret's statement and opinions, and laid before the Academy of Sciences the results of some comparative experiments which had been performed by the Doctor and which supported his theory. He had a room heated to 40 deg. Centigrade by means of a wrought-iron stove, and after having remained in it for an hour, he perspired freely, had a good appetite, and felt no sickness whatever. Similar results attended the use of an earthenware stove, but very different were those which followed half an hour's confinement in the same room warmed to a similar temperature by a cast-iron stove. Here the appetite failed, and an intense headache and sickness were brought on. MM. Deville and Troost, both eminent physicists and investigators, have established that both wrought and cast iron—the latter in an eminent degree—become pervious to the passage of gas when heated to a certain temperature. They have been enabled to state the quantity of oxide of carbon which may, as they suppose, transude from a given surface of metal. They have also shown that the air which surrounds a stove of cast iron is saturated with hydrogen and oxide of carbon. They conclude that cast-iron stoves when sufficiently heated absorb oxygen and give issue to carbonic acid. In the lecture-room at Sarbonne, M. Deville placed two electric bells, which were capable of being set in motion by the diffusion of hydrogen or oxide of carbon, in the room. Soon after lighting the two cast-iron stoves in use in the apartments, the bells began to ring, thus illustrating the correctness of his theory, and showing the danger of stoves of this metal.

We have thus looked at the question of the porosity of iron from 2 different aspects. The first concerns mechanical and the second sanitary engineers. The first means a purely professional, the second a semi-social aspect. In either case the circumstances are interesting and important, and the remedies are, in the one, to fill up the pores of the iron with gruel, and in the other to avoid the use of cast iron in close stoves. The latter question probably affects France more than it does England, but, inasmuch as a great number of cast-iron stoves are in use, it behooves our sanitary friends and the public to take this matter into serious consideration.

MILL FOR MIXING CONCRETE.

We give on page 137 a drawing of a new concrete mixer, designed by Bvt. Major-General Gillmore, and used by him during the past season in the construction of the fortifications on Staten Island, New York.

The drawing is taken from the fourth edition of "General Gillmore's Treatise on Limes, Hydraulic Cements, and Mortars," just issued, and represents the machine as employed by General Duane on the fortifications in Portland harbor, Maine. The mill consists of a cubical box, made of hard wood or boiler iron, measuring 4 ft. on each edge, in the inside.

It is provided on one face with a trap door about 2 ft. square, close to one of the corners through which the box is charged and the mixed concrete emptied out.

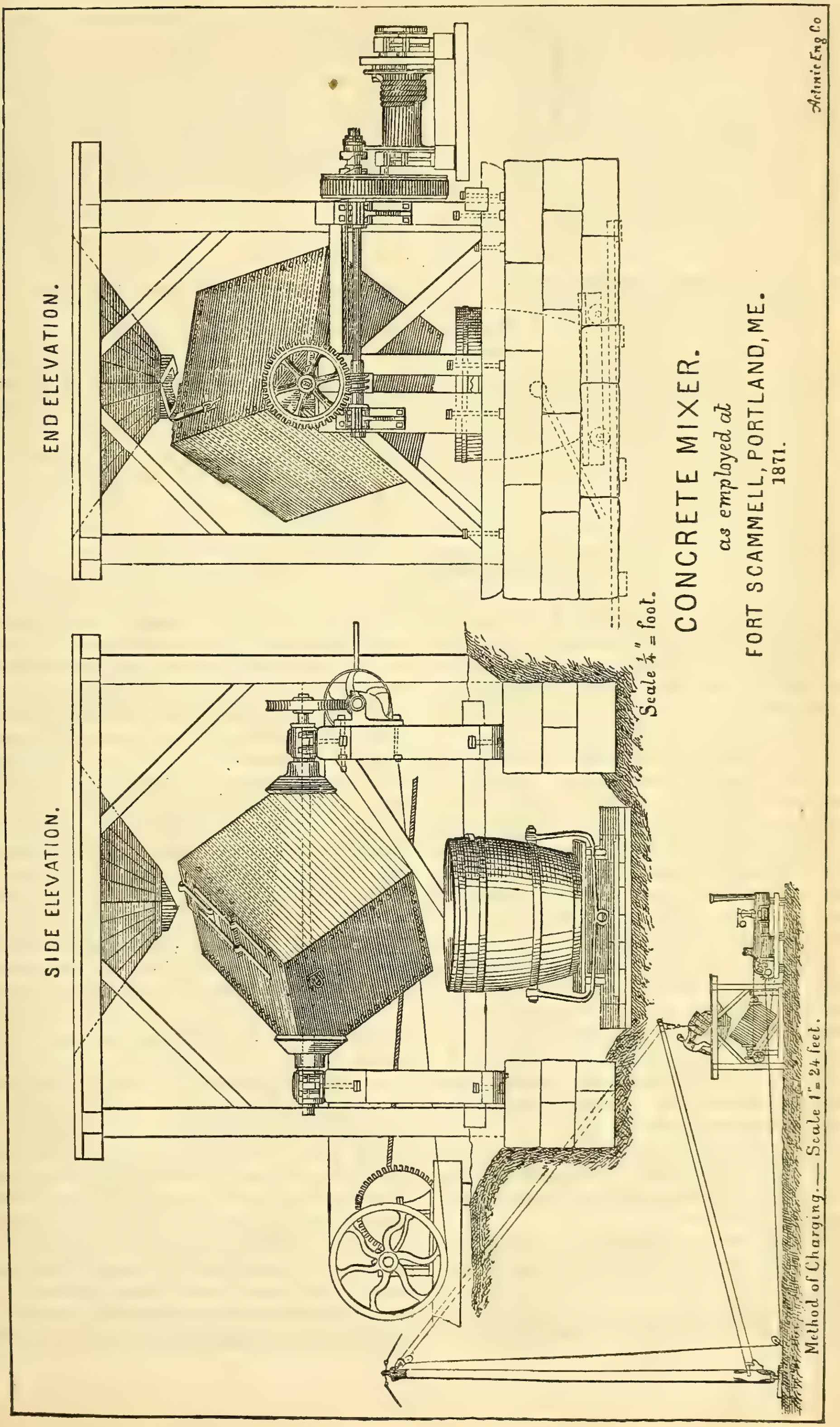
The box is mounted upon and firmly fixed to an iron axle passing through opposite diagonal corners.

By means of a cog wheel attached to one end of the axle, and worked by a screw, a revolving motion is communicated to the box.

The box is charged by means of a large bucket suspended from a crane of sufficient sweep to reach the mortar bed on one side and the piles of broken stone and gravel on the other. The same bucket is used in conveying the concrete mortar and the coarse materials into the box, one measure of the mortar alternating with from 2 to $3\frac{1}{2}$ measures of the broken stone (or gravel, or a mixture of both), depending on the quality of the concrete required.

If the capacity of the bucket is one barrel, say 4 cubic ft., a suitable charge for the box when making Portland cement concrete, will be, 2 buckets full of mortar (8 cubic ft.); 5, 6, or 7 buckets full of mortar, coarse material (20, 24, or 28 cubic ft.); 2 buckets full of mortar to 7 of the coarse materials; the ingredients of the mortar having been proportioned with the same view to economy, will produce a concrete containing the least admissible quantity of the cementing substance.

In making Rosendale cement concrete the charge will generally be, 2 buckets of mortar (8 cubic ft.); 4 or 5 buckets of coarse material (16 or 20 cubic ft.). Eight revolutions of the box, made in less than 1 minute, are found to be quite sufficient to produce the most thorough incorporation of the mortar with the broken stone and gravel. Every piece of stone, and every pebble and gravel become completely coated over with mortar. Indeed the trituration of the contents of



CONCRETE MIXER.
as employed at
FORT SCAMMELL, PORTLAND, ME.
1871.

the box is so complete, that it is not necessary to mix the mortar beforehand. The ingredients of the mortar, the cement, lime (if lime be used), sand and water, after being properly proportioned by measure and rudely mixed together with shovels, require no further preparation, but may at once be placed in the box with the coarse materials. After mixing, the trap door is opened and the contents deposited on the platform below, by 2 or 3 revolutions of the box.

One box of the capacity above described (4′ × 4′ × 4′ on the inside) will easily mix from 95 to 100 cubic yards of concrete in one day of 10 hours, and will do the work very much better than it can be done by hand, and at a saving of from 20 per cent. to 25 per cent. in the cost of labor.

ON WATER METERS AS IN USE BY WATER COMPANIES.*

By Mr. JOHN REID, F. R. S. S. A.

From "The Engineer."

Mr. Reid at some length explained the functions of the water meter, and some of the diffculties attending its construction, due to the non-elastic character of water and the conditions under which it is supplied and drawn off for consumption.

Water meters may be divided into two distinct classes: low-pressure and high-pressure meters. The first are represented as a class by those which discharge definite quantities of water by successive and intermittent actions out of measuring chambers of known capacity into cisterns situated underneath for its reception, the mere weight of the water being generally employed as the moving agency.

The high-pressure class delivers the water at higher levels than themselves, and are impelled in some cases by the mere velocity of the eurrent of water passing through them, but in most instances by the pressure alone. A variety of working models and drawings of the best known forms of meters were exhibited and explained, in most of which the working parts were numerous and complicated, as well as costly in construction. Mr. Reid then stated that he had some years ago studied the subject, with the view, if possible of devising something simpler and cheaper as a water meter than those already known, and as the result of his labors exhibited, for the first time, a diagram and a working model of a meter prepared and fitted up by himself, of which he gave the following general description:

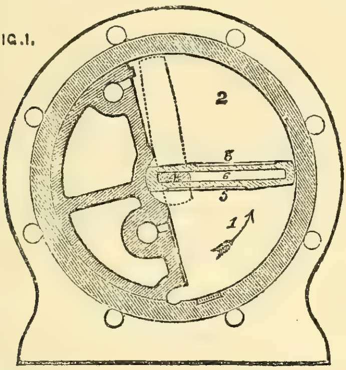
Instead of employing the ordinary form of piston, traversing a cylinder alternately from end to end, and hampered by the friction of packing, stuffing-boxes, and multiplicity of movements, I have adopted a light and easy-fitting metallic piston of a rectangular form, revolving on one of its edges around the axis of a short cylinder, while its opposite edge sweeps the inner circumference of the cylinder, and moving so freely that a few inches of water pressure would be sufficient for its impulse. The small amount of leakage that might pass the edge of the piston is not to be measured by the greater or lesser head pressure of water, but is obviously proportioned to the resisting weight of the piston only, and therefore the amount of such leakage per revolution or per action has to be added to the volume discharged by each stroke, and taken account of by the registering index. The chief novelty in this instrument consists in the compound kind of movement performed by the piston within the measuring cavity of the meter. Although the piston always moves round in the same direction, it cannot be strictly termed a rotary motion, and as it does not return backwards it cannot be termed a reciprocating motion, although partaking a little of the semblance of both. The second peculiarity is in differing from all other water meters, in which the sole moving agency is the water pressure; in my contrivance the impelling force is derived from the water pressure and the force of gravitation, acting alternately and independently. The action of the piston he likened to what takes place when turning a card over on one edge on a table, sliding it back to its original position, turning it again in the same direction on its opposite edge, and so on as before.

A short discussion followed, and most

*Abstract of paper read before the Royal Scottish Society of Arts.

of the members who spoke complimented Mr. Reid on the simplicity and ingenuity of his invention. Professor Fleeming Jenkin said he had a very high opinion of the merits of the invention, and he ventured to hope that the Society might claim the honor of first having had before it the coming meter, which was to enable the public to check the enormous waste of water prevailing in all great towns. The cordial thanks of the Society, he thought, were due to Mr. Reid.

FIG. 1.



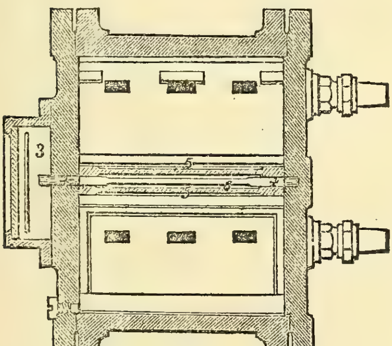
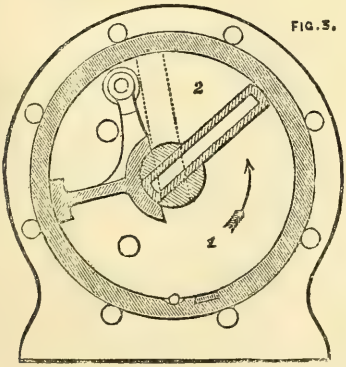


FIG. 2.

FIG. 3.



The annexed diagram and description will better explain the general construction and action of the instrument:—

Figs. 1 and 2 are vertical sections at regular angles of the instrument, Fig. 3 is a modification. The measuring chamber 1, 2, is a cylindrical segment rather larger than a half-circle; the counter wheels or index are within a glass-fronted box 3, and are acted on by the revolving spindle 4. The piston 5 is rectangular, and is connected to the spindle, passing through a slot in the piston, or the piston may itself pass through a slot in the spindle, as in Fig. 3. One edge of the piston 5 works in contact with the inner surface of cylinder, whilst the opposite edge works into a concentric cylindric cavity of smaller radius formed in the chord side of the chamber. The chord side of it is vertical or inclined, the inlet for the liquid is below the central cavity, and the outlet is above it. When the piston is in the position shown, the liquid entering below lifts it upwards and round the course till nearly parallel with the chord, at which time the lower edge of piston escapes from the central cavity, and slides down by gravitation over or through the spindle, and thus translating the axis of revolution from one end of the piston to the other, when it again ascends by the pressure of the inlet from below, while the liquid above is forced outwards by the ascending piston through the outlet port above. The opposite sides of the piston at the ends are slightly bevelled off to insure the piston sliding down just before it comes in contact with the chord surface.

The officers of several German railways have again reported on the necessity of notching the bottom flanges of rails, and it is stated by one railway company that, on a line laid with cast steel rails without notched bases, a dangerous longitudinal shifting of the rails occurred. Generally, however, the practice is not found injurious, though it is thought preferable to have it done at the ends of the rails only, the corners of the notch to be carefully rounded off in all cases.

M. Hesling states, in the "Journal de Pharmacie et de Chimie," that even long before milk becomes sour there are generated in it very small organized spores of an Ascophora species.

THEORY OF THE ATMOSPHERIC ENGINE.

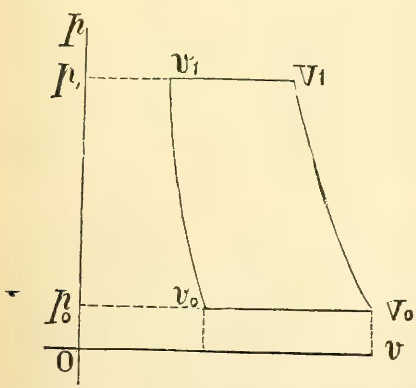
By EMILE LECLERT.

Translated from "Annales du Genie Civil."

I. It is easy to trace the diagram of a thermic atmospheric engine by generalizing Watt's method.

In our theoretic apparatus, in order to obtain conditions clearly defined, we shall suppose that the walls of the containing vessel are impermeable to air. We shall suppose that an apparatus consisting of a *working cylinder*, draws the air into the heating chamber with a tension p_1 and a temperature t_1 and passes it into the atmosphere; while another apparatus, a *feed cylinder*, supplies the heating chamber with air at a temperature θ_0 and a tension p_0. These are generally the constituent elements, whatever may be the combinations.

For greater simplicity we shall construct our diagram for 1 kilog. of air driven into the chamber, and 1 kilog. of cold air taken from the atmosphere, so that it may be the expression of the work realized by a kilogram of fluid. We take the cylinders, with a section of 1 square metre; so that, estimating the tensions p



in kilograms to the square metre, the elementary work corresponding to a slight displacement of one of the pistons, may be represented by the rectangle of the sides; one representing the displacement, the other, the tension p; and the volumes generated and paths described by the pistons will be expressed by the same numbers.

This being assumed, the quadrilateral v_1 V_1 V_0 v_0 in the figure, referred to the axes—one of pressures, the other of volumes—will give the following relations: The abscissas of the points are designated by the letters at the several points.

1. The working cylinder introduces into the heating chamber 1 kilog. of air, with pressure p_1 temperature t_1, and corresponding volume, V_1. This kilogram of air afterwards loses its tension, and its volume increases with diminishing tension, according to a law represented by the curve V_1 V_0, a law which is suited to the case of gas confined in an envelope impermeable to heat. Expanding till its tension falls to p_0, its volume being V_0 and its temperature t_0, it is then discharged into the atmosphere. The area p_1 V_1 V_0 p_0 represents the work obtained per kilogram and communicated to the heating chamber.

2. The feed cylinder takes a kilog. of air from an atmosphere at the pressure p_0 and the temperature θ_0 and with a corresponding volume v_0. This kilog. of air is then driven back; its volume decreasing with the increase of pressure, according to the law represented by the curve v_0 v_1 (a law which is suited for the compression of gas in an envelope impermeable to heat) until its tension reaches p_1, that of the heating chamber, its volume being v_1, and its temperature θ. The area p_0 v_0 v_1 p_1 shows the work per kilog. communicated to the heating chamber.

The difference of the two areas above given, *i. e.*, v_0, v_1, V_0, V_1 = S, represents the total work to a kilogramme of air, actually realized, in the complete action of the apparatus.

II. To study an atmospheric engine is to calculate and discuss all the elements of the diagram v_0, v_1, V_1, V_0. At each of these vertices v_0, v_1, V_1, V_0 are to be considered the groups of quantities v_0, p_0, θ_0; v_1, p_1, θ_1; V_1, p_1, t_1; V_0, p_0, t_0.

On the other hand each kilogram of air—

(1) receives from the chamber a certain quantity of heat of q_1 heat-units, to pass with temperature θ_1 from the point v_1 to the point V_1, with temperature t_1; (2) gives up a quantity of heat q_0 in passing from the temperature t_0 of the point

V_0 to θ_0 of the point v_0. If a denotes the specific heat of the air under constant pressure, a quantity considered independent of the pressure, then

$$q_1 = a\,(t_1 - \theta_1) \text{ and } q_0 = a\,(t_0 - \theta_0).$$

This specific heat a is to be distinguished from the specfic heat under constant volume, which we shall call b, and represent by a constant number.

The difference $q_1 - q_0$ is a quantity which disappears in the action of the apparatus.

The area S, the value in kilogrammetres of the work obtained, obviously depends on the elements which the diagram determines.

The laws of Mariotte and Guy Lussac are admitted as true (within practical limits of tension and temperature). If v denotes the volume of 1 kilog. of air at the temperature t and tension p, the quantity

$$\frac{v\,p}{1 + a\,t} = c$$

is a constant number.

The first question is to determine the nature of the curves $v_0\ v_1$, $V_0\ V_1$ of cut-off in an envelope impermeable to heat.

Now the abscissas of these curves are constant, that is

$$\frac{V_0}{v_0} = \frac{V_0}{v_1} = h \qquad (1.)$$

These curves being traced, it becomes possible to calculate S by ordinary methods. But the theory of heat furnishes us with a remarkably simple and convenient relation. The ratio of S to the quantity of heat disappearing, *i. e.*, $q_1 - q_0$, is a constant number E; which is what is called the mechanical equivalent of heat. Hence

$$S = E\,(q_1 - q_0).$$

or

$$S = a\,[(t_1 + \theta_0) - (t_0 + \theta_1).]$$

III. To discuss the expression, let us suppose the temperature of the air to be θ_0; that of heating t_1. S will be a maximum when $t_0 + \theta_1$ is a minimum. Let us find the condition of this minimum. Since h (1) denotes the ratio of the dilatation of a kilog. of air passing from θ_0 to t_0 under a constant pressure p_0; then

$$\frac{1 + a\,t_0}{1 + a\,\theta_0} = h. \qquad (2.)$$

From θ_0 to t_1 under same pressure let the ratio for same volume be

$$\frac{1 + a\,t_1}{1 + a\,\theta_0} = H.$$

$$\therefore \frac{1 + a\,t_1}{1 + a\,t_0} = \frac{H}{h} \qquad (3.)$$

But it is a property of the curves $v_0\ v_1$, $V_0\ V_1$ under these circumstances that

$$\frac{1 + a\,t_0}{1 + a\,\theta_0} = \frac{1 + a\,t_1}{1 + a\,\theta_1}.$$

Hence

$$\frac{1 + a\,\theta_1}{1 + a\,\theta_0} = \frac{1 + a\,t_1}{1 + a\,t_0}.$$

and by (3)

$$\frac{1 + a\,\theta_1}{1 + a\,\theta_0} = \frac{H}{h} \qquad (4.)$$

Adding (2) and (4)

$$\frac{2 + a\,(t_0 + \theta_1)}{1 + a\,t_0} = h + \frac{H}{h}.$$

This found, H is a quantity determined by the data of the question, as long as h varies with t_0. It will be seen that, in the last equation, the product of the two terms in the second number is constant and equal to H. It follows directly from a familiar theorem of algebra that $t_0 + \theta_1$ is a minimum when

$$h = \sqrt{H}, \text{ that is when } t_0 = \theta_1.$$

Hence this conclusion: In the case of a maximum diagram the temperatures of air at entrance and discharge of the working cylinder are equal.

In Ericsson's engine the ratio of p_1 to p_0 is less than that given by the maximum diagram; *i. e.*, $\theta_1 < t_0$. Ericsson caused both the discharged air at temperature t_0 and the supply air to pass over the same series of metallic sieves. These may be regarded as a recipient of heat capable of imparting to the discharged air at t_0, an amount of heat afterwards to be transmitted to the air at the point of entering the heating chamber whose temperature is θ_1.

If, in an engine, $h = \sqrt{H}$, the equality $\theta_1 = t_0$ follows. In this case the metallic sieves are of no use. If $h < \sqrt{H}$ or $\theta_1 > t_0$ they become a disadvantage.

COAL has been discovered in Rajpore and Kummun, in the territories of his Highness the Nizam. Miners have been sent to ascertain the extent of the seams.

RESULTS OF THE GAUGE CONTROVERSY.

By T. McDONOUGH.

Written for "Van Nostrand's Magazine."

So much has been written by men of ability on both sides on the question of broad versus narrow gauge, that it would seem as if evidence enough had been offered to allow us to sum up the matter And that conclusions might now be drawn which would show satisfactorily to which of them preference should be given; or at least, if neither of them is best applied to all roads, the reasons why one of them is better adapted to certain classes of roads than the other, should be deduced.

Although the narrow gauge advocates claim that economy both in first cost and also in operating is in their favor, the economical results are not alone to be considered in a decision of the question. The owners and those who operate the broad gauge roads seem to unite in their opinion that the system of distribution by means of the wide gauge having already compelled the abandonment of most of the exceptionable gauges, is now too well established to be broken up for the uncertain advantages that a narrower one may offer; even admitting the advocates of a narrow gauge make their claims good, and this is not wholly conceded. For example, should a road diverging from Springfield, Mass., adopt the 3 ft. gauge it would not only be cut off from the roads in that State centring at Springfield, but from the benefits of distribution throughout the West. Wheat from any part of that great granary can now be contracted for, to be delivered at any point on a railroad within a radius of 30 miles from Springfield without breaking bulk, and return freights made in like manner; but all such comity of commerce would be thrown into confusion by introducing another gauge and with it a Babel in the railroad world.

It should be noticed that by viewing the narrow gauge as a change to be made from a broad one by taking out a central section lengthwise of the road, the amount of masonry, earthwork, and ties, that is saved is but small; and also that the principal economy in construction is derived from the use of a lighter rail; but when it is proposed to adopt such a rail on roads of the ordinary gauge, with an equipment to correspond, and in this way to gain the principal advantages of the narrow gauge, viz., cheaper construction and less dead weight to haul, the answer is made that such a course would be going backward, that the heavy rail has displaced the light one from the demands of traffic, and that as economy of haulage has gradually increased the weight of the engine to 30 tons and over, the heavy rail is a necessity, and though more costly, it gives a better return than a lighter one would do with engines hauling lighter trains, and that 40-ton engines with full loads on 60-lb. rails give a better return on the capital sunk than 20-ton engines on cheaper rails.

It would seem that nothing could be advanced against such facts; the weight of the rail being governed by that of the engine, and the economy of heavy loads being admitted, that no improvement could be made by adopting a lighter superstructure.

But it is possible that the discussion of the gauges may bring about a result similar to that which has been reached in the medical profession by the advance of homœopathy, which promises to cure by infinitesimal doses, against the regulars, who relied on the *quantity* they administered. The Faculty, whilst ridiculing the theory, go so far as to adopt it partially, by giving smaller doses than formerly, and mankind is the gainer, without deserting the regular profession; and in like manner the roads with the uniform gauge may be gainers by adopting the strong points of the narrow gauge, without departing greatly from the system approved of by past experience. The necessary weight of rail in both systems is determined by the load on the drivers, as the load on each wheel of the cars is usually much less than that on the drivers.

One of Fairlie's double truck engines on the narrow gauge, weighing 20 tons, has $2\frac{1}{2}$ tons weight on each driver. One of the ordinary gauge 30-ton engines, with 20 tons tender, has usually the same adhesion of 20-ton, but each of the drivers carries from 5 to 7 tons, requiring a proportionally heavy rail.

In one case, the adhesion due to 20

tons weight of engine is all utilized with a weight of $2\frac{1}{2}$ tons, tending to crush the rail at any one point, and in the other there is the adhesion from 20 tons also utilized out of 50 tons weight, but with 5 tons or more crushing the rail, which must be made more than twice as heavy as in the first case. It is evident that an improvement is desirable which will utilize more of the dead weight, whilst the weight upon a single wheel is lessened at the same time, and this must be done without complicating the machine, or lessening its ability to conform to roads already built.

The weight now thrown on a single wheel in freight cars may amount to $3\frac{1}{2}$ tons; should the weight on the driver be reduced to that amount, a 40-lb. rail could be substituted for the 60-lb., and the substantial saving of the narrow gauge construction gained.

The following sketch of a plan to reach this end with only slight changes in the present machine, is offered as a suggestion that may lead to something practical when the importance of the result is more generally appreciated than it seems to be at present.

Taking the machine as now built, put 4 coupled drivers under the tender with 14 tons weight upon them, and throw the same weight upon the engine drivers, that is 28 tons for adhesion with $3\frac{1}{2}$ tons on each wheel, the same load which the car wheel carries, the remainder of the weight of tender and engine will be thrown on the truck wheels. With such an arrangement of drivers, 4 under the tender and 4 under the engine, the power must be transmitted from the engine to the tender drivers, without cramping the freedom of the tender to conform as now to the curves of the road. It is proposed to do this in the following manner: The tender and engine are to be coupled by a centre-pin, and a shaft with cranks on its ends is to be held vertically over the tender axle which is nearest to the engine and about 6 ft. above it, by 2 bearings from that axle, so that the shaft must move vertically with it and not be affected by the springs of the tender. In like manner the horizontal movement of this shaft will be governed by 2 rods that connect it with the rear axle of the engine. This additional shaft would then be supported and controlled by 4 bearings, each 2 of them resembling a letter A with one leg vertical over the tender axle, and the other inclined and reaching the engine axle; with the shaft at the vertex of the A. The power is to be transferred by rods from the drivers on the engine, connecting their crank-pins with pins in the cranks of the additional shaft, and thence to the tender drivers. This arrangement would permit the axles of both engine and tender to conform to the radii, which cannot be done with any that has been proposed heretofore.

Some arrangement similar to this which will give increased adhesion and less weight on each wheel, without the complication of the Fairlie double engine, will insure to the present gauge the principal advantages in construction of the narrow one, without any essential variation in that type of road which is the result of past railroad experience.

A CLASSIFICATION OF STEEL.

By THOMAS M. DROWN.

From "The Bulletin of the American Iron and Steel Association."

Steel-producing processes have of late years multiplied so rapidly, that it is by no means an easy matter to keep track of them all, much less to remember the nature of each individual process. A comprehensive classification of the different methods of making steel, combined with a simple nomenclature, would not only be a great assistance to the memory, but would also serve an useful purpose in clearing away the fog of mystery with which the subject of steel-making is enveloped in the minds of many. An exhaustive classification was made by Wedding of Berlin, some time since, and published in the "Berg-und Huttenmannische Zeitung," October 29, 1869. It was, however, almost too detailed for ordinary purposes, and an attempt to translate the same into English involved the coining of so many polysyllabic words, that the result bordered on the ludicrous.

The classification, which I desire to propose, has at least the merit of simplicity and conciseness. The main divisions only are provided with names. Suitable designations for the subdivisions were very much to be desired, but it is doubtful whether they would ever be generally adopted. I therefore content myself in pointing out clearly the natural divisions of the subject, so that any variety of steel can at once be classified.

I. CRUDE STEEL.

1. From the ore direct, by reduction and carburization. Ore steel.

2. From pig iron by decarburization. Pig iron steel.

(*a*) By means of gaseous oxidizing agents (air, steam, etc.). Ex. Bessemer process, etc.

(*b*) By means of solid oxidizing agents (ore, saltpetre, etc.). Ex. puddling process, Heaton process, etc.

R. From wrought iron by carburization. Wrought-iron steel.

(*a*) By fusion with pig iron. Ex. Martin process.

(*b*) By fusion with coal or carbonaceous matter. Ex. Mushet's process, Indian process.

(*c*) By heating in charcoal—without fusion. Ex. cementation process.

(*d*) By heating in atmosphere of carburetted hydrogen — without fusion. Ex. Macintosh process.

II. FINE STEEL.

1. By fagoting crude steel. Shear steel.

2. By remelting crude steel. Cast steel.

To go further into the details of manufacture would only serve to complicate the classification. The object in view is to present clearly the main feature of every process.

It will be evident, on a moment's reflection, that the raw material for steel making must be iron ore, pig iron, or wrought iron. In the case of ore, the process consists mainly in reduction and carburization. This can be effected by gaseous carbon (carbonic oxide, carburetted hydrogen, etc.), or by direct mixture of the ore with coal. The resulting product may be required to be subsequently fused or otherwise treated, yet the main feature of the process is the reduction of the ore.

In the second subdivision where pig iron is used, the object is the removal of carbon, silicon, manganese, etc., which is effected by oxidation, the agents employed being either free gaseous oxygen, as in the case of air, or oxygen in combined solid form, as in the case of ore, saltpetre, etc. Here the iron may be molten as in the Bessemer and the puddling process, or simply at a red heat, as in the process for making malleable castings.

Where wrought iron is used the process becomes a carburizing one. The carbon added may be in form of carburetted hydrogen, in form of charcoal or carbonaceous matter, or pig iron may be used in proportion to its amount of carbon. As in the previous case, the conversion may take place both with and without fusion.

There are many processes which may be assigned to more than one of these divisions. Thus the Bessemer process belongs mainly to the division I., 1, *a*, inasmuch as the decarburization of the pig iron is effected by a current of air. But as ordinarily practised the result of this operation is the production of wrought iron, which is subsequently converted into steel according to division I., 3., *a*, that is by the addition of pig iron. No classification could be made to take into account all the details of a process without becoming cumbersome; it is sufficient for our purpose to indicate the most prominent feature of a process.

The fusion of wrought with pig iron is placed under the head of wrought iron steel, as in this case, the wrought iron greatly preponderates.

There are, further, varieties of steel, which are named after substances which enter into their composition as: Titanium steel, Chrome steel, Tungsten steel, etc, These can be arranged in the above classification by prefixing their characteristic names, as: Titanium pig iron steel.

Again, there are many steel processes in which an essential feature is the employment of substances to remove impurities, as sulphur and phosphorus. These might be designated by affixing the name of the substances employed to the steel produced. Thus in the case of the Heaton process we would have pig iron steel by saltpetre, in the case of the Sherman process pig iron steel by iodine.

These terms, it must be confessed, are somewhat unwieldy, yet their descriptive nature may in some respects render them preferable to those in ordinary use.

The classification may also serve the purpose of showing at a glance the possibilities involved in the manufacture of steel.

LOCOMOTIVE WORKING EXPENDITURE.

From "Engineering."

It is but a short time since we directed attention to the somewhat abnormal position which a locomotive occupies amongst steam engines generally as regards the small opportunities it affords for being worked with a greater economy of fuel. A locomotive with its imperfectly protected and unjacketed cylinders, placed in a position which facilitates the carrying into them by the steam of any water mixed with the latter, cannot be declared a high class type of steam engine; but it is nevertheless a type which has done good service, and it is, moreover, one which it is difficult to modify with any really economical results under the circumstances which govern locomotive working. As we pointed out in our former article, the great obstacle to the improvement of the locomotive engine as a steam user is the small number of hours per annum during which such an engine is actually working. This small proportion of working time limits the annual monetary saving which any given improvement can effect, and renders the charge for interest on the additional cost of any such improvements disproportionately large. Taking the mean gross cost of an engine as £2,400, and the mean annual cost of fuel as £180 per annum, we showed, on the occasion to which we have referred, that even if, by doubling the cost of an engine, it was possible to save the whole cost of fuel without incurring any extra charges for depreciation and repairs, the saving would but pay interest at the rate of 7½ per cwt. per annum on the extra outlay. The sum above taken as the annual cost of fuel per engine, namely, £180, was deduced from an examination of the accounts of ten of the principal English railway companies for the last half year of 1870; but we this week publish on page 310 a table giving a more complete account of the expenditure on 20 of our principal lines, which will enable us to found our deductions on a broader basis.

The Table referred to—which, we believe, will be regarded with much interest by a large section of our readers—contains data derived from the locomotive accounts of the various railways enumerated for the first 6 months of the present year, and from it we find that the average cost of fuel per engine during that period was £72, or at the rate of £142 per engine per annum. Now, if we assume, as we may justly do, that any improvement made in a steam engine should pay, on an average, at least 15 per cent. per annum (5 per cent. for interest on capital, and 10 per cent. for depreciation) on its original extra cost before it can be regarded as being a source of economy, we find that any improvement capable of saving 10 per cent. of the fuel used, must, if applied to a locomotive, cost less than £100, or that otherwise such an improvement will not prove really an economical one. This deduction agrees with that made in our former article, namely, "that any fuel-saving appliances added to a locomotive must, to avoid their use being attended with a loss, effect on the average a reduction of fuel amounting to 1 per cent. for each £10 of their original cost." This, it must be borne in mind, is an average result, and it is one also applicable to individual lines of great extent and variety of traffic, such as those of the London and North-Western, Great Northern, and similar companies. But although this is the case, a closer investigation of the Table shows us that there are certain lines on which the conditions of working are so exceptional that the above deductions entirely cease to be applicable. This, for instance, is the case with the North London Railway, where the cost of fuel per annum is £264 per engine, or nearly double the average; and still more noticeably so in the case of the Metropolitan Railway, where the annual cost of fuel per engine rises to £528, a sum more than 7 times the average, and more than 10 times that incurred per engine per annum on the London and North-Western Railway. The effect of this on the expenditure which it is justifiable to make on fuel-saving improvements is very striking and, in fact, it will be seen that, whereas, on the average, any improvements which are capable of saving 10 per cent. of fuel should not cost more than £100 per engine, in the case of the Metropolitan Railway such an improvement might be profitably employed even if it increased the cost of each engine by £700. In making this statement we are, of course, supposing that the improvement is of such a character that its maintenance would not involve an annual charge greater than 10 per cent. on its original cost. In the same way we find that on the North London line an additional expenditure of about £190 per engine, would be justifiable for the purpose of obtaining a reduction of 10 per cent. in the consumption of fuel, and a similar statement would apply to the London, Brighton, and South Coast Railway. In the case of the Metropolitan Railway the high cost of fuel per engine per annum is due partly to the high price of the superior kind of coke which it is necessary to employ on that line, partly to the heavy work to be done, and partly to the great mileage obtained from the engines. This mileage, it will be noticed, is more than 80 per cent. in excess of the average, and is nearly 8,000 miles per annum greater than it is on any other line in the country. The causes we have above enumerated place the Metropolitan Railway in quite an exceptional position, and afford opportunities for the employment on it of economical expedients which would be inadmissible on other railways.

Turning now to the data given in the Table, concerning the expenditure of oil, tallow, etc., we find the average annual cost per engine for these materials to be £32. Applying the same rule as before, namely, that any improvement must effect an annual saving equal to at least 15 per cent. on its original cost, we find the average maximum justifiable expenditure to be about £2 per engine for each 1 per cent. of lubricating materials the improvement is capable of saving. In the case of the North Staffordshire Railway, however, where the cost of oil, tallow, etc., is £60 per engine per annum, an expenditure of £4 per engine might be incurred to obtain a saving of 1 per cent.; while on the Great Western, where the annual cost of lubricating material is but £18 per engine, an expenditure of about 18s. per engine would be justifiable to effect a similar economy.

Taking the average results recorded by the Table, we find the various items which go to make up the total of locomotive expenditure to be as follows :

			Per cent.
Salaries, office expenses, and superintendence....			2.35
Running expenses:	Wages	29.7	
	Fuel	24.1	
	Water	2.	
	Oil, tallow, etc.......	5.35	
			61.15
Repairs and renewals:	Wages	19.4	
	Materials.........	17.1	
			36.5
			100.0

Taken altogether, the statistics contained in the Table which we publish this week, entirely confirm the arguments—founded on less complete data—which we have used on previous occasions when writing of locomotive economy. Leaving out of the question such exceptional cases as the Metropolitan, the whole bearing of the evidence available is to the effect that, in the case of a locomotive engine, improvements tending towards economy of fuel are of secondary value as compared with such improvements of construction as will enable a greater annual amount of work to be got out of each engine by reducing the time lost in making repairs; and that in proportion as the work done per engine per annum is increased, so also will be increased the opportunities for the employment of refinements tending to produce economy of fuel.

PROPOSED ROMAN EXPLORATION.

From "The Builder."

Fresh notice is being attracted to the subject of the exploration of the buried relics of Rome, archæological or artistic, to which we called the attention of our readers last September. Mr. J. H. Parker, C.B., whose excavations in Rome have already led to discoveries of no small value, is again in the field. He proposes to raise a fund of £50,000 by way of capital of a limited company, to be formed with the object of purchasing land in Rome, exploring it to the utmost, and then reselling it—it is presumed at a profit—for building purposes. There can, we apprehend, be but little doubt that explorations such as Mr. Parker and his friends have now, for some time, conducted in the Eternal City, will in future only prove practicable under widely different conditions. While the incubus of priestly government brooded over Rome, the very pride which even the Italian peasant takes in the relics of the ancient glories of the country was extinguished by the harsh tyranny of greedy ignorance. Rome, though still calling its chief dignitary by the Pagan title of Pontifex Maximus, claimed to be regarded only as a Christian city. The walls of Romulus, the *cloaca* of Numa, the temples of Republican times, were only to be endured in ecclesiastical Rome if christened and whitewashed. Even the very names of that earlier time, with which the essential forms of the Papacy are so much more closely connected than its advocates choose to admit, were often whimsically travestied in monkish garb. It is difficult to recognize the *Xystus vetus* under the title of Santo Sisto Vecchio, or the *Mutatorium Cœsaris* in San Cesareo; but transmutations of the kind may serve to show the manner in which Roman antiquity was dealt with by Romish ingenuity.

No doubt can be entertained that English archælogists will find their position at Rome very different under the Italian Government, from what it was under the Papacy. The great object, under the latter, was to collect *bajocci*, under all and every pretext. To attract foreigners to spend money in the city, was the sole industry of Rome of late years. Even such mites as the payment of rent or damages for leave to dig were not to be despised. Nothing can be more characteristic than a little incident casually mentioned by Mr. Parker. Last winter, under the friendly offices of the Monks of St. Gregorio, he obtained permission of their lessee to open a pit in a garden belonging to the convent, for the consideration of £10. The pit was accordingly sunk to the depth of 24 ft., and discovered the well-known pavement of the Via Appia, and fragments of the travertine gateway built by Domitian for the Porta Capena; showing that there were two archways to this gate. No sooner, however, had the excavation proved thus productive of information, than the *locatario* comes down on the straightforward Englishman. £10 was the price for opening the pit. That bargain was settled. Now the pit must be filled up again. There was no bargain for keeping it open! So good Mr. Parker had to pay a further sum of £20 for permission to keep his pit open for 6 months!

This is only a characteristic instance of the manner in which Englishmen, bent on historic research, are regarded in Rome. How much can be got out of them is the one question; nor, we will venture to assert, is any foreigner safe from plunder, unless he avails himself of the services of an Italian lawyer. These gentry alone, from long practice, can meet the fertile and inexhaustible ingenuity of their own countrymen in what they call matters of business, but which we, poor simple islanders, are apt to regard as ably-utilized opportunities for swindling.

Now without supposing that any great moral change has been effected in the Roman citizen by the hoisting of the Italian tricolor on the Quirinal, it must be borne in mind that the state of things has undergone a great alteration. The new Government, though inheriting very much of the spirit of the old, yet owns some deference to the public opinion of Italy, and, perhaps, some to that of Europe. It cannot afford to wrap itself up in contemptuous indifference. It may be, and we believe is, quite as reluctant to do any act of justice that involves parting with a grain as was either of the most corrupt Governments which it displaced. But it must at all events put some face on the matter, which it was not necessary for its predecessor to do. Now the Italian people take a great pride in all visible proofs of their former grandeur. Not a peasant so dull but he respects the relics of antiquity. This respect must be evinced by the Government. Exploration and restoration, even if they cannot be made self-supporting, form a popular mode of giving employment to some of the legion of idlers who seek to eat the bread of the country; and the prosecution of works of this nature looks respectable, both at home and abroad. Thus the uncovering of Pompeii is being steadily prosecuted, at the expense of the State, under the able and modest direction of the Chevalier Fiorelli, who, as private secretary of H.R.H. the late Count of Syracuse, had the care of much of the archæological research carried on at the expense of that unfortunate Prince. Then the Italian Parliament has voted £12,000 for the purpose of excavating the whole of the Palatine Hill, with the slopes round it, as far as the Forum Romanum and the Arch of Janus on the north, the Via Sacer and Clivus Sacer on the east, the Arch of Constantine on the south, and the Circus Maximus on the west. Already have discoveries been made which indicate that the pestilential condition of Rome is due rather to the constant violation of the laws of health, whether as regards the decency of the living or the disposal of the dead, than to any mysterious terrestrial *miasmata*. Even supposing, then, the anxiety of the Government for discoveries to be real and practical, it would be their duty to supervise all excavations carried on in Rome ; to see that their course and consequences were strictly subordinated to sanitary considerations, and that they formed integral portions of some well-considered and comprehensive plan.

Now, if we were to learn that an Italian Archæological Society had been formed for the protection of Avebury or of Stonehenge, for the restoration of Uriconium, or for the excavation and leaving open those portions of tesselated pavement or other Roman work which have been, within the last few years, discovered in London, we should hardly be apt to treat these volunteers with too much gratitude. After all, it is not clear whether a better case could not be made out for an Italian protectorate of English—or rather, Roman—archæological remains in this country, than for an English occupation of those of Rome. The Italians do respect their relics,—the English, as a people, do not. The rapid destruction of some of the grandest relics of an unknown past which has taken place, since the time of Stukely, at Avebury, would have been an offence against the public law of Italy, and would have been repressed by authority if (which is most unlikely) any Italians had been found brutal enough to attempt it. Then the great military roads that opened our previously pathless forests ; the fortified camps which have left their names, in the form of the affix of Chester, in so many counties, even as they have left traces of the normal plan of the Roman *Castrum* in the 4-way streets of Gloucester, and many other cities of Roman origin ; the actual remains of imperishable reticulated brickwork, or of tesselations, the materials of which were taken from yet older buildings ;—in all these things the Italians of to-day have a hereditary interest even more direct than our own. Nor can we, on any possible grounds, pretend to so much right to explore Italy as an Italian archæologist might claim for the exploration of England.

Under these circumstances, we think that the plan now suggested, should it meet with enough support to assume a definite and digested form, is perhaps the only one under which it will be feasible for English enterprise to make any satisfactory progress in the recovery of the ancient historic evidence of Roman archæology. To purchase land, at a fair price, in the open market ; to investigate thoroughly all structural remains ; and subsequently to sell the land for building, is a scheme in itself possible. Moreover, it has the advantage of not being one altogether of an eleemosynary character. There is some prospect, if not of a return, at all events of a dividend, of the original subscription to the subscribers. Many a man would be likely to contribute his £10 on the understanding that, if not exactly an investment, yet it was a purchase of a chance. Archæological knowledge would certainly be increased, if the money were wisely expended. And the fair probability would remain that the shares might be worth their nominal value.

Of course, something distinct and definite will be announced by Mr. Parker as the arrangement in virtue of which he invites subscriptions. Some board of directors must be named, some responsible trustees for the proposed investments. Above all, it will be desirable that intending subscribers should be informed under what legal advice their money is to be laid out. On this, indeed, the whole stability of the project will depend, so complicated are the claims affecting landed property in Italy, and so usual is the appearance of some lurking prior mortgage, after the purchase money has been paid, that a degree of caution quite foreign to our English habits is necessary in any transaction of this nature in that country. Moreover, it is necessary, to avoid trouble hereafter, that the good-will of the Government should be assured. Here, again, an Englishman will naturally inquire what possible effect can the good or ill will of a Government have on the purchase of property from the owners? He will find that in this case it has much to do with it. The powers of interference with his proceedings are great, and may be exercised, at the instigation of some insignificant enemy, in a very annoying manner. Objects of art, for instance, are claimed by the Italian Government as a sort of treasure-trove. Wherever a claim of this kind exists, are to be found all sorts of rights of inspection and conservation that may prove intolerably vexatious if any ill-feeling exists. Mr. Parker tells us that he has obtained written permission from the Italian Government to make excavations in any part of Rome. Of course, in coming forward as a promoter of a company, he will desire to discharge himself of any unnecessary responsibility, and will take care to print and publish the exact text of this permission. It will be necessary also to show that the local laws with reference to public companies are exactly and formally complied with. In fact, there is a good deal which must be done before subscriptions to a limited company can with propriety be received.

We treat of the subject with much sympathy with Mr. Parker. He has devoted much time, labor, and money to the service of archæological discovery. Laboring under the disadvantage of the absence of a professional education, he has yet produced works that are valuable to the architectural student as well as to the archæological amateur. To say that he has a hobby, is only to say that he is one of those men to whom science is generally indebted for most of the impulses to its pursuit. To say that he makes mistakes, is only to say that he is one of those whose discoveries are not limited to the side of the highway. He has spent, he tells us, half of his fortune in Rome ; and it would be well for the world if the pursuit of unwritten evidence had many such disinterested votaries. His discoveries have been neither few nor small. His labors have been incessant. Our own hearty concurrence, moreover, is due to the moral tendency of his labors. At a time when criticism has pushed its analysis to the extent of absolute destruction of our records of the past, it is very much to find a man who comes honestly forward to say, "Romulus was not a mythical personage, for here is the masonry of his wall ; Roman history is not a series of fables, for here are the traces of kings, consuls and emperors." If Mr. Parker went no farther than he has done, he would rank as a benefactor to the most important of sciences, the philosophy of history. It is the more needful that he should be kept free from any entanglement with what he has himself experienced to be a very untrustworthy administration ; and that any investment of English money, to such an extent as $50,000 in Roman land, should be placed under the most formal guarantees competent to the laws of the country and to the administration of the kingdom. Long and bitter experience has taught us how ready the various Italian Governments are to encourage the flow of English money to fertilize the long arid soil, either of the wastes around Brindisi or of the valleys covered by the *debris* brought down by the Po. But when it comes to question of return,—*Hic labor hoc opus est.* The old maxim that no faith is to be kept with heretics appears still to be honored at Florence. Englishmen, we know, *are* heretics.

Mr. Parker suggests no less than 30 explorations and excavations to be pursued in the coming winter. Among them, that which strikes us as the most important, serving in no small manner as a key to more, is the completion of the marble plan of Rome, attributed to the 3d century, and mentioned by the historian Panvinius. Fragments of the plan were discovered in 1867, in an excavation undertaken by the monks of S.S. Cosmo and Damiano. Its completion, and publication by means of a permanent photographic process, is not only most important as an archæological proceedure, but would be of great service to the exploration as furnishing a sort of block plan, by reference to which the course of discovery can be conveniently indicated.

The incidental mention made of this important record of ancient topographical science, as the 22d out of 30 objects proposed for investigation during the coming winter, is an indication, in our opinion, of the main cause why the efforts made for the exploration of Rome, no less than those for the exploration of Jerusalem, have hitherto attracted so much less public support than the actual importance of each subject demands. Professionally, educated archæologists are very rare.

Very imperfect views are but too common as to the relative value of the remains of different eras of structural art; and pre-historic archæology is much confounded with architecturel antiquity. Hence it happens that interest in the actual discoveries of other people is not uncommonly very vivid. Many a man may find pleasure in grubbing about on his own account, turning up, with equal content, a denarius of Carausius, or a silver penny of Queen Anne, who cares but little to know what discoveries are in progress in the adjoining county. Again, many a man may be capable of making a good survey, of grasping the military features of an ancient fortification, of tracing the course of an aqueduct, or of carrying out detail afler detail of local investigation, who has not the logical and orderly grasp of mind needed for the clear enunciation of the great historic problems to be illustrated by the result of his toil. And again, a man thus fitted to direct a survey of the kind, can only, by the rarest chance, have the habit of the publicist, the power to bring before the world, clearly and incisively, the main outlines of his case, in such a manner, as to win or to command attention. It is certain that this must be done, in order to attract the interest of any large portion of the public. Of Rome every one has heard, and of Jerusalem every one has heard; but what we may expect to discover in either locality, for what we should look, and what will be the value of the discoveries we seek,—these are matters which the public must have explained to them, not only before they will take the trouble to send post-office orders but even before they will so much as read through a column of details in small print in the daily papers. In this preliminary statement of their object, illustrated, year by year, by the clear description of the successive discoveries, each referred to its proper head, both the Roman and the Palestine explorers have been signally deficient. In the latter case it is the less excusable from the block outline which we ourselves supplied ("Builder," 4th January, 1868) of the 7 successive cities that have been reared on and around the hill of Zion; the 18 successive architectural eras indicated by history; and the locality, or other features, distinctive of each. To burrow at haphazard, lighting now on a coin of the Seleucidæ, now on a lamp of the Arabic caliphs, now on a balistic ball of Titus, and now on a charred fragment of the cedar roof of Solomon's porch, is interesting enough for those who are engaged in the pursuit, but will never attract public support, unless as the detailed and orderly prosecution of a well-arranged scheme.

The exploration of Jerusalem, however, while it cannot claim support on the ground of such personal and disinterested exertion as Mr. Parker has devoted to the exploration of Rome, is illustrated by two important features, the excellence of which we cannot too strongly urge the latter investigators to copy. The admirable education of the Royal Engineers, in surveying and mapping country, has been turned to the best account in Palestine; and the Ordnance maps which have been completed and engraved, are permanent contributions of great value, both to topography and to geography. Again the photographs taken by the non-commissioned officers of the same corps are clear, well-defined, and effective.

In the repeated exhibitions to which Mr. Parker has invited us, of the products of his own labors, we have had more than once to regret want of due attention to these two important particulars. A map of Rome and its environs, on which the various discoveries could have been indicated, would of itself have been a valuable production, and would have enabled people to see at a glance what was in hand. The definition of Mr. Parker's photographs, as a rule, has been extremely imperfect. Out of more than 2,000, there are but few that any one would care to look at as pictures. As records they are, no doubt, of much value, though the appearance of the prints does not promise any permanence even of their present indistinct details. One-fourth of the number of views, taken with artistic selection and with mechanical beauty, would have set many of us half wild after the exploration. It is not the case that the climate of Rome is naturally unfavorable to taking good negatives in the camera; for those taken by M. Braun, and reproduced by the carbon process, are some of the most admirable works ever yet effected by any branch of graphic art. If the services of this photographer are available, a very few prints from his factory would be worth a great number of inferior, *quasi*-amateur productions.

In Rome itself exist relics of the cradle of European society. While Regal, Consular, Imperial and Papal Rome are not divided from one another by the broad lines of fire and of steel that Nebuchadnezzar and Titus drew across the walls of Jerusalem, still the principal buildings of the various eras, however grading into one another, are to be recognized by well marked features. Portions of the *Arx* of Romulus yet remain on the Palatine Hill. The stones employed are 4 ft. long, 2 ft. wide, and 2 ft. deep. They are split off from the tufa quarries by means of iron wedges, exactly as these quarries are worked in the present day, and do not appear to have been dressed, or but roughly so, with the axe. The building of the later kings shows some reduction in the size of the blocks. Fragments of the wall of Servius Tullius are to be found on the eastern side of Rome, running on the high ground for a mile, and connecting, by a great *agger*, the several *arces* of the famous seven hills. In this wall the stones are wrought and closely fitted, and secured to one another by iron clamps, not run in with lead. From these samples of the art of the mason 2,600 years ago, down to the most finished and splendid productions of the time of Hadrian, archæology can trace both the progress of the builder's craft and the growth and development of the city. In the catalogue of photographs, printed in 1868 by Mr. Parker for private circulation, are to be found a valuable historic series of the successive styles of work, and a general distribution of the photographs into appropriate classes. It is much to be regretted that this arrangement was not carried on and perfected. The catalogue of the 1,800 photographs exhibited in New Bond street last year is without any order except that in which the photographs happened to be taken. Mr. Parker's materials are rich ; his knowledge is extensive. For such a systematic programme as we have indicated, he could readily supply ample data. The authorities for dates, very briefly referred to in his preface last year, should be distinctly set forth. The general scheme of his researches, divided into historical chapters, should follow. Results already obtained, referred to their proper heads, would then be regarded in their proper light ; and archæological and historical students, seeing what was actually in hand, would be likely to strain their energies to find Mr. Parker the support which he requires.

Whatever be the complexity, or even the error, of detail, whoever be the laborers—the Archæological Society of Rome, the newly-projected company, the Italian Government, or any native and private explorer—the value of a competent survey of Rome cannot easily be overestimated. We have good hope that the time has now arrived when this important object will be steadily and worthily pursued. However much or however little may henceforward be effected by English funds, it must not be forgotten that Oxford has sent forth a pioneer, who labored for the elucidation of Italian history while Italy was no more than a geographical expression. The mere presence at Rome of Englishmen able to pass educated criticism on the efforts of Signor Rosa (which seem to be rather in the direction of what is called restoration than of discovery proper) is important. The whole of learned Europe will listen with interest to clear and impartial accounts of any attempt to draw back the veil of so many centuries. We are happy to call attention to the present proposal of Mr. Parker ; and we need not say that we heartily wish good speed to every well considered effort to throw light on the archæology of Rome.

THE TIN TRADE.

From "The Mining Journal."

The very large deliveries of tin during the last few months are a certain indication of an extending demand, of a kind apparently uninfluenced by price. And thus the miner begins to ask why, if the present high price does not diminish the demand, a still higher one should not be obtained? In other words, why he should not get £175, or even £200, per ton for English refined, instead of £150? To many the question may appear a bold one, whilst others will deprecate any further advance in price, because, forsooth, from a comparison of years, they consider the values now ruling extremely high. It must be admitted, indeed, that few, if any, can remember higher prices than those of to-day being paid for any length of time. An examination, however, of the present condition of the trade can but prove that the miners are not altogether faulty in their premises, or rash in anticipating what seems, indeed, to be more than probable.

No doubt the purchases for the continent, of tin and tin-plates have been exceptionally heavy; first, in consequence of the stoppage of all trade during the Franco-Prussian war; and, second, from the fear of an excessive duty on all raw produce imported into France. But there has been a cause far more important than either of these at work—the replenishment of the camp furniture of both of the contending hosts, and the re-furnishing of the desolated homes of France. It will take a long time to make up for what has been actually wasted, and meanwhile there is that steady onward march in the necessities of the human race. It is, however, unnecessary to dwell here on the incontrovertible fact that the demand for tin is steadily on the increase, since the deliveries, both from English and continental stocks, speak for themselves. But it is rather to the question of supply that we must turn as affecting the future price.

On referring back, we find that Straits tin was quoted on the 1st of this month £137 per ton; on Nov. 1, 1870, £127; and on Nov. 1, 1869, £123. Now, with such a marked increase of value, one would anticipate a very great and rapid increase in the supply; and yet what do we find ?—that the actual quantity of this kind afloat for London and landing, was on the 1st of this month almost identical, certainly not 100 tons more than was afloat and landing on Nov. 1, 1870, when the price was £10 lower. A comparison between 1869 and 1870 would make this still more striking. From Straits tin we might turn to Billiton, and from Billiton to Banca, with exactly the same result—that the price, so far as these great centres of production are concerned, has been unable to stimulate the out-turn in any appreciable degree. Whether it is from want of labor we cannot say, but we may fairly conclude that, let the reasons be what they may, the islands of Banca and Billiton cannot be altogether, as some have reported them, of solid tinstone. Further investigations as to the other great tin-bearing centres of the world will still further demonstrate that high prices have failed to increase the production ; in fact, in the case of the Bolivian mines, to which we are about to refer, we shall find that high prices tend rather to diminish than to augment the yield of the mines. Situated far inland from the Peruvian coast, these mines are worked almost solely by Indians and half-breeds, whose only object in labor is to earn sufficient for the bare necessaries of life, spending all that they are paid beyond that in feasts, often of weeks' duration. There is an undoubted abundance of tin there, but the unsettled state of the country, as well as the inhospitable region of the mines, are barriers hitherto too great for European enterprise. And until there is an organized system of labor from this country, there is little probability of our seeing a large import of Peruvian tin. Now, the above two great sources of supply are generally those spoken of when foreign tin is named. At the same time, to do justice to the subject, we must mention that Australia will be likely to send us some pretty fair quantities in the future ; whilst nearer home, in Portugal, there are tin deposits almost "virgin." The little tin we have seen from this latter country is most excellent in quality, and the containing rock most promising in appearance ; but as far as yet worked the veins do not appear sufficiently strong to justify the outlay requisite to bring any large quantity of tin into the market.

Let us now turn to Cornwall, one of the most ancient seats of tin mining known. There alone we see a response to the high prices now ruling. New mines are being started, and the old ones vigorously prosecuted. But it is a curious fact, that despite all her advantages, with an abundance of skilled labor, and large invested capital, there has been no sufficient augmentation in the yield of the mines either to flood the market or even to stay the upward move in price. Nor, indeed, have those who command her produce been as yet able to snatch from the hands of the importers of foreign tin the regulation of prices. The truth is, that, although there have been new mines opened, no very large discoveries of tin have been lately made, and if it were not for the increased richness of some of the older mines, Cornwall would be in the same position as those other countries we have named.

There are several reasons why we may never expect a sudden glut from over-supply. First, no source has yet been found of a lasting kind which is not in the form of a vein. Now, to extract the tin ore from such veins requires a long time, powerful machinery if the mine be extensively worked, and great labor to get it out. Of course, important discoveries might be made any day, but even then it would take many of them to influence the present market much. Again, beyond the difficulties of mining tin, there will always be, as a drawback to any pouring in of that metal on the market, the difficulties of separating it from the containing rock before it is fit for smelting. This question of preparing tin for the smelter is one of very great importance, as affecting our present inquiry, since, from the mode of smelting, or rather reduction, as we may term it, of the tin stuff, otherwise oxide of tin, by means of carbon in the form of anthracite, it is necessary for the miner to render the mineral almost absolutely pure, it being practically impossible to separate in the process of smelting any large quantity of impurity. Scattered through the containing rock, as most tin ore is, the process of cleansing it is most difficult. First, it must be finely pulverized, then washed and washed again, then burnt and washed again, until its very collection is tedious in the extreme.

Those who have followed us thus far must, we think, readily admit that from the side of supply there is more to be said in favor of higher than of lower prices. It may be fairly urged on the other hand, that the present sources have more than amply supplied, in years gone by, as much tin as the world has required. Admitted that it was so, and further, allowing that the supplies are not less than in those times of glut, there still remains that ever increasing demand for all metals. In days gone by many cooking utensils were made of pure tin, whilst many were made of pure copper, but now they are almost all made of iron, with a thin film of tin to protect it, in other words, of tin-plates. The tin required to make one of the old plates would now cover some dozens of cooking utensils; but the demand for the latter is in the proportion of 1,000 to 1 of what the former was. As we pointed out in an article on the Copper Trade in last week's Journal, vessels and utensils of tin-plate are fast superseding, even amongst semi-savage nations, the more showy and costly ones of copper. In India this is especially the case; and it only requires a spread of intelligence amongst the inhabitants of that vast territory, and what is, perhaps, equally important, a few lessons on the beauties of the interest table, to abandon what is costly for what is cheaper and equally durable. Such changes as we are now speaking of are the work of time, and cannot be effected rapidly; but that they are inevitable no one can doubt.

One last word on the effect of a rise of £10 in the value of tin on the cost of a tin-plate saucepan. On referring to the quotations of the tin-plate makers, we find that a rise such as that we have named means an advance of 3s. on a box of tin-plates. Query, how many saucepans can be made from one box of tin-plates? We are not tin-plate workers, but we think the equivalent advance in the value of each saucepan would be almost inappreciable. We are compelled thus to the conclusion that the demand for tin will be little, if at all, influenced by the price. We must not be misunderstood. We do not assert that the price of tin will be higher than it now is; we merely would point to those who are continually reducing all questions to precedent, how the market has stood without injury the repeated upward movements of the last few years.

GOLD STANDARD IN GERMANY.—It is intended that 1 lb. of pure gold shall be coined into 46½ pieces of 30 marks, 3 marks equal to 1 thaler, or into 93 pieces of 15 marks, or 69¾ pieces of 20 marks, the latter nearly equal to 1 sovereign, as they are almost of the same standard, 900 gold by 100 copper; or into 41 85-100th pieces of 30 marks, weighing 1 lb., and so on in proportion. It is provided that wear and tear is to be at the expense of the Imperial Government, an example it were vain to hope the English Government will follow.

WHAT SHOULD A ROAD LOCOMOTIVE WEIGH?

From "The Engineer."

We have excellent reasons for believing that there is a great future for steam on the highways of the civilized world. At this moment all the agricultural engineering firms who have constructed traction engines are deluged with inquiries as to the capabilities of these machines and the prices at which they can be supplied. It would be sheer waste of time and space to recapitulate facts concerning the work which has been done by such engines. It is now known as well as anything can be known, that in Great Britain and Ireland, in the United States, in South America, our colonies, India and throughout Europe it has been proved that steam power can be applied with advantage as a means of locomotion, wherever there is a fair approximation to a decent road. And with all this, and in spite of the success which has already attended on the exertions of inventors, it is certain that the traction engine is yet in its infancy. Before many years elapse it is probable that a very great trade will be done in the construction of road locomotives for all sorts of purposes; and the fact furnishes our excuse, if any is needed, for returning again and again to the subject. Complete believers as we are in the ultimate success of the system, we are not blind to existing defects as represented by the practice of various designers and manufacturers; and our duty to our readers, no less than our own inclination, demands that we should from time to time endeavor to aid, to warn, and advise those engaged in the construction of road locomotives. And we undertake this task in the light of an extended acquaintance with all the phases of existing practice, acquired during many years of patient observations, and with the certainty that we can speak, and think, and write with more impartiality on the subject than any individual who is practically engaged in making and selling machinery.

The most remarkable performance ever accomplished by any road engine is that of the Ravee in her double journey from Ipswich to Edinburgh and back. We have already given many particulars of the first half of this trip, and, thanks to the courtesy of Lieutenant Crompton, we are now able to place a complete tabular statement of the results of the entire trip, as a whole, before our readers. It will be found at page 357. We have already stated that, in our opinion, serious mistakes have been made in designing this and her sister engine, the most important error consisting in their excessive weight. The accuracy of our views on this subject has been impugned both in our own pages and elsewhere by those who hold different views, and we think that, with all the facts before us, it may be worth while to discuss the point here as to how far weight could or could not be reduced without impairing efficiency.

It is obvious that in approaching this subject it is simply impossible to express an opinion of any value as to what the engine ought or ought not to weigh, until we know exactly how much power it was necessary she should exert. Now it so happens that on this point Lieutenant Crompton is unable to supply any precise evidence acquired from indicator diagrams, nor are we aware that any attempt has ever been made to regularly indicate a traction engine on a long trip. We must therefore endeavor to get at the facts in another way. The experiments conducted at Wolverhampton last summer proved that Thomson engines developed 1-horse power indicated for every 33.3 to 37 lbs. of water evaporated. Making due allowance for the conditions under which the Ravee worked, we believe we shall not be far from the truth if we assume that the expenditure of each 34 lbs. of steam represented one indicated horse-power.. A glance at our table will show that the average consumption of steam—otherwise water—was 19.8 lbs. per ton per mile with the shoes on the wheel, and 14 lbs. per ton per mile without. Averaging these again, but making a small deduction for the fact that the shoes must, in regular service in countries where the roads are not always dry, be more frequently used than not, we have an ordinary consumption of 17 lbs. of steam per ton per mile. It is not very easy to get at a true corrected average of the speed of the Ravee, because of short stops for horses, which could not be accurately noted, but we shall not be far astray if we take it at 7 miles an hour. Therefore, according to the data before us, the Ravee used per ton 3.5-horse power indicated to propel her at 7 miles per hour; the gross load was 19 tons, and the engine must consequently have exerted 66.5 indicated horse-power. Going up hill, no doubt, this estimate was considerably exceeded, while in descending inclines it was reduced; but on the average of the whole journey our estimate is very near the truth, we believe.

A velocity of 7 miles an hour is 616 ft. per min.; 66.5-horse power is 2,194,500 foot-pounds; dividing this latter number by the former we get 3,562.5 lbs. This represents the number of pounds gross resistance overcome by the engines at the given speed; dividing this by the number of tons in the load, 19, we have very nearly 187.5 lbs. per ton resistance. Now it appears absolutely impossible that on average roads, such as Lieut. Crompton ran over, the resistance could be anything like this. If he had run on soft gravel the whole time, the resistance would have been but 100 lbs. per ton, while on a good macadamized road it falls to 70 lbs. as a maximum. If we take it 100 lbs., which is excessive, it still follows that 87.5 per cent. of the useful work done by the engines was absorbed in overcoming their own resistance. There is no escape, from this conclusion, which, considering the great excellence of Messrs. Ransome's, Sim's, and Head's workmanship, is almost incredible, except we assume either that the engines did not really exert anything like 66.5-horse power, in which case the water must have left the boiler in the form of wet steam —we will not say priming; or else that Lieut. Crompton is wrong in his estimate of the quantity of water actually used, which is, we think, out of the question, or, lastly, that the presence of Thomson tires on the engine and omnibus, increased the rolling resistance of the load to nearly double what it would have been without them.* It is not fair to bring in the influence of inclines, because in so long a journey the inclines must have balanced each other in effect, and the average resistance must have been just the same as though the engine had traversed a perfectly level—we do not say uneven—road. Let the facts be accounted for how they may, it still appears that it will sometimes be right to estimate the resistance which the engines of a high speed road steamer have to overcome at as much as 187.5 lbs. per ton, including their own friction, or 100 lbs. per ton for the resistance of the load alone, without engine friction.

The loaded omnibus hauled by the Ravee may be taken as weighing 5 tons. Let us put this as a representative or typical item, and assume that the average work required from any engine intended to perform the duties of the Ravee will consist in hauling 5 tons at 7 miles an hour average velocity. It follows from what we have said that this duty will be exposed by 616 × 500 = 308,000 foot-pounds of work per min.; this is 9.33-horse power. If the engine also weighed 5 tons, we should have sufficient power to propel both load and engine with 18.66-horse power; and if we add about 50 per cent. for engine friction, the work might still be done for about 27-horse power. There is nothing assumed here, we think, that is not borne out by Lieut. Crompton's data, except the item of engine friction, and for this we allow an enormous margin. It will be objected that a traction engine, weighing 5 tons, would not be able to exert 27-horse power indicated, in the first place; secondly, that it would not possess adhesion enough; and lastly, that it could not carry coal and water enough. The first point is easily settled by the results of experience. One of the little "steam sapper" class of engines, built by Messrs Aveling & Porter, weighing very little over 5 tons, gave out 40 indicated horse-power on the brake with ease at Wolverhampton in our presence. It is therefore certain that an engine weighing but 5 tons can be had which will give out 27-horse power. Indeed, the Field boiler of the Ravee, which, as we have seen, gives nearly 70-horse power, weighs but 2 tons, in spite of its enormous wood-burning fire-box. The objection on the score of adhesion may be settled as easily. A 5 ton engine may be depended upon to take itself and 10 tons up an incline of 1 in 20 in all weathers. No inclines can be met with on fair roads up which a 5-ton engine will not take a net load of 5 tons. We now come to the coal and water part of the question. The tank of the

* Lieut. Crompton does not state the consumption of water whilst standing under steam, but it must have been too small much to affect the results.

Ravee holds 365 gallons for, say, 66-horse power. Therefore, a tank somewhat over one-third of the capacity, or holding, say, 130 gallons, should suffice for the light engine. This weighs 1,300 lbs.—let us say 12 cwt. for water. The Ravee carries 1 ton of coal. The small engine would in the same way do with a little more than one-third the quantity. Coal and water would therefore weigh say 18 cwt., and so the gross weight of our engine would be 5 tons 18 cwt. Something must be added to this, however, because the foot plate must be enlarged as compared with an Aveling engine; but even if we allow a ton for this, and a moderate addition for the coal and water required for the transport of this additional ton, we still find that there is every reason to suppose that an engine can be made which, with coal and water for as long a run as the Ravee can perform without a stop, will weigh but 7 tons, or just one-half the weight of the Ravee.

We have yet two points to consider; the first is the argument that it is the great speed which must be occasionally maintained to make up an average speed of 7 miles an hour, which renders a heavy, or, in other words, a powerful engine necessary; the second point we shall refer to in a moment. Now we snbmit that the fact that a great speed must sometimes be maintained has little or nothing to do with the question. We have no evidence to show that the Ravee ever exerted for more than a few minutes at a time anything like 120-horse power; but even though we had, *cæteris paribus*, the facts would remain almost precisely the same for the 5-ton, or shall we say for the 7-ton, engine. She also could as well double her power for an effort as the Ravee could double hers. The true question at issue is the average power exerted by the engine on a trip of fair length, and if it can be shown that the resistance per ton is independent of the number of tons, and that the light engine can exert the same power per ton of gross load as her larger rival can exert, then any argument based on this question of speed falls to the ground. It must, in a word, be proved that the efficiency increases in a more rapid ratio than weight. But all existing experience with traction engines and road steamers goes to show that each reduction in the weight of an engine augments its relative efficiency. It is true that large engines and boilers make and use steam somewhat more economically than smaller boilers and engines, but there is also reason to think that the road resistance per ton increases with the weight in a very much more rapid ratio. On this score we do not think the advocates of the heavy system can make a single point.

The only remaining argument in favor of the heavy engine which we have now to consider is that the Thomson wheels weigh a great deal. There is some force in this. The india-rubber tires on the driving wheels of the Ravee, for instance, weigh each about 6 cwt. alone; but this difficulty may be got over to a great extent. In the first place, improvements may be made in the wheels by which they may be considerably lightened; and, in the second place, the breadth of tire for the light engine need not, other things being equal, exceed half that of the tires used in the Ravee. The driving-wheel tires of that engine carry nearly 10 tons, or 5 tons a wheel. The weight on both the wheels of the light engine we advocate would not exceed that on one wheel of the heavy engine. On the whole, we hold that our arguments in favor of a light engine cannot be defeated, unless, indeed, there are still some facts in the background which are known only to Lieut. Crompton and Mr. Thomson.

Petroleum Explosion.—A serious explosion of petroleum on board a ship in the Thames took place this week. Vessels laden with petroleum are moored off Erith, and there were three of these vessels anchored near each other. An explosion took place on board the last arrived, and the vessel was at once wrapped in flames, which extended to the two others, but fortunately the nearest one had discharged her cargo, and both were towed out of the way of farther harm. The men on board the vessel that exploded were severely hurt.

A New Ship Canal.—A subject of great importance to the mercantile and manufacturing communities of Liverpool and Manchester has recently been broached, viz., that of a new and independent canal between the two cities. The contemplated monopoly of the carrying trade in the hands of an amalgamated railway company gives additional interest to the suggestion for new means of intercommunication.

THE BEHAVIOR OF CEMENTS AND METALS IN CONJUNCTION.

From "The Builder."

In the course of the inquiry now going on as to the loss of the Megæra, repeated reference has been made to the use of brickwork and Portland cement in filling up between the ribs of iron vessels, and to the protection of iron by means of cement; and this has served to recall doubts we have long entertained as to the safety of bringing metals into conjunction with Portland and other cements.

At a meeting of the Institution of Civil Engineers in 1865, when Mr. Grant's first paper on "The Strength of Cement" was read, Mr. G. Dines, in the course of the discussion which followed, said he feared that Portland cement had a corrosive effect upon iron; therefore when cement had to be in contact with iron, he always used Roman.

Mr. Scott Russell, in reply to this, said Portland cement had been extensively used in the insides of ships to preserve the iron from corrosion; and after 18 years' use he had seen Portland cement dug out of an iron ship, when the red-lead paint and the skin of the iron were as sound as on the day they were put there.

Mr. H. Maudslay thought this fact appeared to show that the cement had not been in actual contact with the iron, as it was protected by the red-lead paint to the extent, probably, of 2 or 3 thick coats. The caution raised with reference to the effects of Portland cement in contact with wrought iron had been made upon the supposition of a fact which did not appear to exist.

Mr. Scott Russell suggested that the inference to be drawn from Mr. Maudslay's observation would be, that wherever cement was used with iron, the iron should be painted with red-lead.

Later in the discussion, Mr. F. J. Bramwell said, a question had been raised with respect to cement placed in contact with iron, which turned out to be a question of cement upon oil. He might say, that having occasion to form a deck upon a floating dock, which deck he did not wish to be combustible, so as to be in danger if a hot rivet fell upon it, nor to be liable to rot if temporarily immersed in water in a tropical climate, and which therefore did not admit of the use either of creosoted or of unprotected timber, he had made every inquiry he could as to the behavior of Portland cement concrete in contact with iron, and he was then having prepared a Portland cement deck, 3 in. thick; but he was afraid that experiment would not settle the question at issue, because, after all, it would only be cement upon oil; all the iron having been steeped in oil when hot.*

Soon after this discussion had taken place, a piece of stout iron piping was bedded part of its length in mortar-brickwork and the remainder in cement-brickwork; but whether it was Portland or Roman cement we are unable to state positively. Within the last two days we have examined the pipe, and find that where the cement was used the iron is destroyed and full of holes, while the other portion of the pipe remains as sound as it was at first.

We give this fact for what it is worth, and do not wish any general inferences to be hastily drawn from it. It may be that particular conditions are requisite to lead to this result, or that certain precautions will prevent it. At any rate, however, it inculcates the necessity for inquiry. Probably a special examination of one of our iron-clads in which cement has been used would not be out of place.

Touching the preservative power of a coat or two of red-lead, we should not be very sanguine, and for this reason. In a certain set of houses the external wall forms the back of the cistern, and the front and sides are of wood. The wall is rendered with Portland cement to form a flat surface; and the lead lining is dressed over cement and wood alike. We have recently examined several of these cisterns, and find that while the lead on the wood front and sides is perfectly sound and good, the lead on the cement has been entirely destroyed, and, indeed, is so changed in character that, from sight alone, it would be difficult to say what the material is.

These facts certainly show that further inquiry in the same direction is necessary, and should be instituted immediately.

* Mr. Grant's paper, with an abstract of the discussion issued by the Institution, forms a very valuable pamphlet. A report of "Further Experiments," by the same author, has been quite recently published, and is also valuable.

RANSOME'S PATENT STONE.

From "The Building News."

It is now a considerable time since we referred to Mr. Frederick Ransome's inventions, and to the toilsome progress by which he had reached a stage in the manufacture of silicious stone, a point at which we thought he might be well content to "rest and be thankful." We have found, however, from a visit to the works of the Company, at East Greenwich, that we were mistaken, and that Mr. Ransome, in the continued exercise of his characteristic perseverance, has personally, and in conjunction with other inventors, Mr. Henry Bessemer, Mr. J. W. Butler, and Mr. Pye Smith, chiefly, been pressing on to fresh triumphs.

It is not necessary to do more than briefly recall the important illustrations of the capabilities of Ransome's stone for decorative purposes, as exemplified in the great capitals of the University, in the Grecian style, recently erected at Calcutta; in the ornate fountain playing in the public gardens at Hong Kong; in the screens, designed by Sir Digby Wyatt, of the Indian Court, Whitehall; in the balusters, vases, and other ornamental "repeats" of S. Thomas's Hospital; and in numerous other situations. The more recent applications of the principles of Mr. Ransome's invention are to useful rather than to decorative purposes, but in this direction and for the material applied to structural purposes, new and important inventions have also been made and patents for them secured.

Strange though it may seem, it is none the less true, that from the production of a material that only an expert can tell is not real Portland stone, inventive skill has passed on to produce admirable imitations of red and gray granite, and porphyritic rocks of all kinds, including their large crystals of felspar; black, gray, Sienna, and other kinds of marble, veined and mottled in the structure, with a truthfulness to nature that it would baffle the skill of the most accomplished "grainer" to surpass. These interesting specimens are shown with truly-worked mouldings, and a glassy polished surface, equal to productions in the natural rocks.

A further improvement in manufacture, or rather an additional application of the patent stone, relates to the production of stone caissons for sea and river walls, piers, etc., and other hydraulic works. In this application of the material, Mr. Ransome is associated with Mr. J. W. Butler, hydraulic engineer. One of these caissons has recently been sunk, with complete success, at the entrance to the London Docks. It is 35 ft. deep, and passes from the bed of the river down into the London clay. The cylinder is in sections of about 4 ft. deep; they are 9 ft. in diameter and 8 in. thick, and have tongued joints. The whole caisson was sunk with ease in the course of two days.

The works connected with structures that are founded under water are of two distinct classes, the preliminary and the permanent, both of which are very costly. The preliminary works include sheet piles, coffer-dams, iron caissons, and the like, which may be superseded by these stone caissons, that are of a material of great strength, and adapted to serve as permanent piers and abutments. When sunk, they have only to be kept clear of water by pumping, and filled up with concrete, brickwork, or other material. The materials and process of manufacture of these caissons are totally different from those of Mr. Ransome's former method. The ingredients include, in the proportions found best, ordinary large sharp-grained sand, or even fine gravel, hydraulic cement, ground carbonate of lime, soluble silica, with an adequate quantity of Mr. Ransome's silicate of soda. In this combination the silicate of soda is decomposed, the silicic acid combining with the silicate of alumina and the caustic lime of the Portland cement. The caustic soda thus set free has an affinity for, and combines with, the soluble silica of the mass, producing again more silicate of soda, which is again attracted and converted, until the whole is utilized and completely fixed. The stone is hard, strong, and dense, and admirably adapted to resist the influences of heat, cold, water, or moisture. As regards its strength, it may be enough to say that it is proved to resist crushing force up to 4 tons, or 8,960 lbs., on the square inch. Granite resists to from 8,000 to 12,000 lbs., Bramley Fall to 5,120 lbs., Portland stone to 2,630 lbs., and wrought iron to from 36,000 to 40,000 lbs.

The grindstones manufactured at East Greenwich, in vast numbers and of all sizes, are not now a novelty; but our readers will probably be "surprised to hear" that large numbers of these stones are constantly sent to the great engineering works at and near Newcastle, where they cost more money than the native article which is there at home. It is an old saw that "Scotsmen and Newcastle grindstones are found all over the world." The proverb may continue true of Scotsmen, who are to be met with in every clime, and particularly on the green spots on the earth's surface, but it is ceasing to be true of Newcastle grindstones. The new patent article is now sent in great numbers to the colonies and foreign countries, and it is not to be wondered at that it is preferred to the natural stone; it is perfectly homogeneous, cuts more keenly, wears quite evenly, and has no yolks.

Another utilitarian purpose to which Ransome's invention is now applied is to the production of millstones for grinding wheat, rice, and other grains. The ingredients in these differ but slightly from those that are mixed for the production of grindstones. Care is exercised in the selection of hard sharp sand, with good cutting power, and in fabric the mass is harder than in the case of the grindstones. The millstone is moulded with grooves as deep as it will be safe to wear the stone. These are filled up to flush with the upper part of the stone with Portland cement, plaster of Paris, or other material softer than the stone. In use, these grooves wear to a sufficient depth to permit the flour to escape in the ordinary manner. If these stones can even do as much work, and as well, as the French burrs or granite millstones hitherto in use, it is palpable that they must possess immense advantages. They have now been in constant use in Brussels and other places for many months, and the *ascertained* advantages realized from their use are: lower first cost, they are driven with less power, do more work, and require no dressing or disturbance until they are worn down to the bottom of the channels. There is another advantage secured by the use of these stones, but *it is only a question of life and death.* The men who dress and fit the blocks of which the French burr stones are built, never live to be older than 32 or 33 years, and the dressers of burrs, at work, sustain proportionate injury from that part of their occupation. They are all choked and poisoned with the dust of flint and steel. From inevitable death, as a result of their occupation, there is no escape. The economical aspect of the question may be the most important in the estimation of some jolly millers, but it may be hoped, surely, that all will be ready to take in the humanitarian view, if only as a make-weight.

Another of the novelties to be seen at East Greenwich Stone Works, is the manufacture of discs for saw sharpening and other uses. These are of various sizes and thicknesses, from one-eighth of an inch thick upwards. The chief ingredients in their composition are emery and silicate of alumina. The pugged material is packed into a strongly made iron mould, into which a die is fitted, and the material is pressed by a hydraulic ram, exercising a pressure of 70 tons. The discs are dried and hardened either with or without artificial heat. The performance of these emery discs is surprising. Their keen cutting power is to be seen at the works, East Greenwich, and also at the works of Messrs. Allen, Ransome & Co., King's-road, Chelsea. Some of these discs have been in constant use daily at a large saw mill, and at the end of three months are not nearly worn out. One of these discs, ¼ in. thick, will attack a saw blade an eighth of an inch thick and cut it at the rate of 6 in. per minute! This valuable substance —emery—is found in large quantities in various parts of the world, as at Naxos, in the Archipelago, Spain, Poland, Jersey, Turkey, Austria, Smyrna, Minnesota (United States), etc. It is of the nature of corundum or adamantine spar, but really consists of the flinty shells of deposited masses of animalculæ. It seems likely that these emery discs will come into extensive use for many purposes to which they are capable of being applied, in addition to saw sharpening, and not unlikely that they may exercise an important influence upon file cutting and file using.

The works of the Ransome Stone Company and East Greenwich are well worthy a visit by any one interested in construction and cognate arts.

PATENT FUEL.

From "Engineering."

"Take 3 parts of the best Newcastle coal beaten small, 1 part of loame, mix these well together into a masse with water, make thereof balls, which you must dry very well. This fire is durable, sweet, not offensive by reason of the smoke or cinder as other coal fires are, beautiful in shape, and not so costly as other fire, burns as well in a chamber even as charcoal." The foregoing extract, taken from a fragment of an old book supposed to have been printed about the year 1670 or 1679, and headed "An excellent Invention to make a Fire," contains probably the earliest reference on record to the manufacture of what is now commonly known as artificial, or patent fuel. At that date, however, very different reasons existed for preferring such a fuel to coal in its natural state, to those which now prevail, as an inducement to its manufacture. When coal was first introdured into London, the greatest possible objections were raised against it, and the manufacture of the compound fuel above described is evidence of the strong prejudice then entertained to the use of coal. In the life of Mr. Locke, we are told (1679) that the Earl of Shaftesbury required Mr. Locke to return to London. "He accordingly returned thither, but not being wholly recovered, and finding himself afflicted with the asthma, he could not tarry long at London, the sea coal that is burnt there being so very offensive to him." Poor Mr. Locke! But it may reasonably be asked, what would be his feelings now, could he pay a visit to his former haunts in London upon a foggy November day? Fortunately, we inhabitants of this great metropolis, in the 19th century, have become so far acclimatized, as to be not only above complaining of such trifles as coal smoke, but most of us even wish that the fuel could be obtained more cheaply, so that we might burn more of it. The question then at the present day, which concerns the manufacture of patent fuel, is not one of prejudice, but of necessity; for the waste of our coal resources has at last assumed such gigantic proportions as to have attracted the attention of the Legislature, and no one studying the interesting reports of the late Coal Commission can fail to be struck with the enormous national loss which is now annually endured owing to the want of some efficient means for the economical utilization of the small coal which is now unavoidably made even under the very best known systems of coal working. Probably it would not be in excess of the fact to assert, that fully one-third of the coal now hewn is reduced to that state wherein it becomes known as "small," "slack," or "duff," and not more than two-thirds becomes ultimately burnt in the shape of "round" coal. The small produced in bituminous coal seams will coke well, and it is much used for that purpose; but the demand for coke not being in any way equal to the supply of bituminous small coal from which it might be made, a great proportion of the latter is left underground, and ultimately becomes lost beyond all possibility of future recovery. The small from steam coal will not coke; and hence it is, as a rule, almost invariably left below, as it would not pay to raise it to the surface so long as there is no market for it, and it could only be thrown on one side in a heap, occupying ground which might be better and more conveniently used for other purposes. With the extended manufacture of patent fuel—which at present appears to offer the only means of profitably utilizing small coal to any great extent—not only would a market be provided for small coal which now unavoidably collects at the pit's mouth, but if carried on upon a sufficiently extensive scale, it would afford sufficient inducements to the colliery proprietor to bring up all the small coal that could be raised, together with the round coal. At present this manufacture may be said to be quite in its infancy, and it employs only a very minute proportion of the small unavoidably made at comparatively few collieries, and its results in this respect are wholly unappreciable excepting at a few pits in the immediate vicinity of the manufacture. Thus there is room, as there is also an urgent necessity, for the establishment of works of this nature throughout the length and breadth of the kingdom wherever coal is to be found; moreover, it is quite possible that patent fuel may, from its utilization of small coal, render it possible at some future time, to work seams with profit, which either from their softness and friability, or for other reasons, are now looked upon as worthless.

The first patent taken out for the manufacture of patent fuel was in December, 1799, by one John Frederick Chabannes, but it is probable that the process described above as having been adopted 120 years previously, had in the meantime undergone some improvement. According to this invention, small coal was to be consolidated by mixing it with "earth, clay, cow dung, tar, pitch, broken glass, sulphur, sawdust, oil-cakes, tan, or wood, or any other combustible ingredient, to be mixed together and ground with a wheel in water in a wooden vessel; the mixture is then to be placed in pits provided with drains for the water to run off, and when dry is to be moulded into cakes." Impracticable as the process above described must have been, it no doubt served as a basis upon which many similar patents have been subsequently drawn up. The next invention, dated May 20, 1800, was for putting small coal, together with certain other ingredients, into an oven or kilns, causing the several particles to unite together by fusion; a system which, upon experiment, must have been found to be utterly impracticable. The first really practicable system suggested for the manufacture of patent fuel was one patented by Peter Davey, in 1821, which is the first time that any proposal appears to have been made to form the mixture into blocks by pressing it into moulds. Between that time and now—that is to say, during the last 50 years—the question of patent fuel manufacture has been steadily growing year by year into greater importance, and many are the names of those who have given their attention to the matter. If the mere fact of taking out patents had been sufficient to induce the manufacture of any article in proportionate quantities, we should not now have to complain of the millions of tons of small coal which are being annually wasted. For one reason or another, this manufacture has not kept pace with the requirements of the times, owing probably to this fact, as much as to anything else, that the various patentees in this field of enterprise knew very little about the real merits of the question, desiring rather to see others carry their suggestions into practice than to risk any money upon them themselves. The few patent fuel manufactories that now exist, are upon a small scale only, and are little better than private enterprises, although some of them rejoice in the title of "company." What is really wanted is a company in which a sufficiency of capital for the carrying out of the manufacture on a large scale, is combined with a practical knowledge of the subject by all to whom its interests are confided. As a proof of the total want of the last named qualification in certain instances, it may be mentioned, that among the most common errors of would-be fuel manufacturers, is the one that, by mere mechanical combination of materials, results may be obtained equivalent to a chemical change in the ingredients themselves; thus that, by the mixture of anthracite and bituminous coals, a fuel may be obtained corresponding in its properties to steam, or semi-bituminous, coal; or, that by mixing a very good and a very poor coal together a fuel of a fair average quality may be obtained. Nothing could be further from the truth, for by no means can mere mechanical combination alter the nature of the several ingredients used. In a fuel thus made with a mixture of coals, each particle will burn in the precise manner, and give the results due to the peculiar seam from which it was taken; whilst the pitch, tar, or other medium used for combining the small particles together will, in like manner, give out the flame, heat, or smoke due to its combustion under similar circumstances when not forming part of a block of artificial fuel.

Owing to the convenience of stowage, and that patent fuel occupies much less space per ton than coal in its natural state, the former is chiefly in demand for shipping purposes, and the small coal used is almost exclusively that from the steam collieries. The principal seat of its manufacture is in South Wales, whence steam coal is shipped chiefly for foreign ports; but there is no apparent reason why this manufacture should be so confined to one spot, when it would be equally beneficial in the vicinity of all our coalfields throughout the United Kingdom. For whatever purpose coal from any colliery is used, patent fuel made from the dust of such coal should find a ready market, with this reservation only, that it must be borne in mind that a process of manufacture suitable for steam purposes will not always be applicable to fuel for domestic use, but the converse will not equally hold good, for any process that will produce the latter kind of fuel should be equally good if applied to steam coal. In most of the patent fuel manufactures for shipment for steam purposes an excess of bituminous matter is introduced, either as pitch or tar, which not only would be objectionable to the senses, if used for domestic purposes, but it would require a greater draught in order to secure proper combustion, and consequent freedom from smoke than is usually obtained in domestic fireplaces.

WOOL AND ITS IMPURITIES.*

From "The Mechanics' Magazine."

If it sufficed for the necessities of the divers industries dependent on wool that the carded wool of commerce should be of good color, its fibres smooth, clean, and parallel, we might congratulate ourselves on the progress made of late years in wool carding. But, unhappily, it is altogether different, when we come to consider the same wools with regard to their absolute industrial values; that is to say, their aptitude for taking dyes and their suitability for spinning and dressing. The great majority of wools used at Roubaix are but imperfectly purified from the earthy and fatty matters which they naturally contain, and from those with which they become contaminated in the process of carding, either accidentally, or to facilitate the operation. Now, these impurities are the essential cause of numerous imperfections in each of the subsequent operations, and, if not removed, perfection is impossible, either in dressing, spinning, or dyeing.

Conditioning.—This first operation has for its object to ascertain by absolute dessication the true weight of wool in any bale. Samples are taken from the bulk of the cleansed and carded wool, of which it is desired to know the degree of humidity, and carefully weighed; they are then submitted to a temperature of 105 to 108 deg. By this means the water they contain is evaporated, and, on reweighing, the absolute weight is supposed to be obtained. If the wools were really pure, this mode of ascertaining the value of the wools would be very rapid and sufficiently exact; but it is a matter of fact that all substances dissolved in a liquid hinder its evaporation and elevate its boiling point, and the influence thus exerted becomes greater, with increase of the affinity of the liquid for the substance in solution.

Amongst the most common impurities of carded wool are to be found: Salts of lime, derived from the water in which the wools are washed, and which form, with the oils of the wool and with the soap used, insoluble soaps, which add to the weight and deteriorate the wool, rendering it dusty and greasy; soap, and the substances used to adulterate it; starch, kaolin, resinous matters, silicate of potassa, etc., animal moisture, and glycerine, all increasing the boiling point of water; so that the effect produced on wool by heating to a temperature of 105 deg. is proportionate to its degree of purity, and in no way to the amount of moisture which it contains. Under these circumstances it is useless to deduct the amount of moisture evaporated and estimate the remainder as so much pure wool, since it really contains salts of lime, insoluble soaps, glycerine, etc., which hold water with a tenacity incapable of being ruptured at 105 deg. With this state of things *conditioning* will never be anything but an empty word—an illusion.

Dyeing.—Good dyeing is not possible, unless the wool has previously been thoroughly purified from all fatty matters, and from animal moisture. Bleaching—that is to say, this thorough cleansing and purification—therefore, constitutes an integral part of dyeing, and it is of the utmost importance that it should be most efficiently carried out; in fact the dyer should watch this part of the process constantly.

The next point to be attended to is mordanting. Nearly all the colors used in dyeing require, in order to form a stable dye, that they should have for their base, some metallic substance, the bodies used

* A paper read before the Association of Commerce at Roubaix, by M. Feron.

for this purpose being the mordants. Now, if the compounds formed between the coloring matters and the dyes are insoluble, the compounds formed between the mordants and many of the impurities in the wool—the soap in badly-washed wool for instance—are not less fixed and insoluble. If the mordant be a salt of iron, for example, it forms an insoluble iron soap which effectually prevents the wool from taking a good pure tone of color. In order to get a good result under such conditions, dyers are constantly in the habit of evading the obstacle, and dyeing without any mordant whatever; so that mismanaged cleansing gives rise to fraudulent dyeing, colors thus put on being merely superficial and valueless.

NITROGEN IN NATURE AND ART.

From "The American Exchange and Review."

The aqueous ocean which covers nearly three quarters of the area of our globe, and which performs so essential a part in the economy of nature, from its peculiar characteristics presents features of the greatest interest to the student of physical science. Not less interesting, however, and of far greater amplitude, covering both sea and land, is that vast aerial ocean, extending into the regions of space, and known as the atmosphere, in which we live, and move, and have our being. This immense expanse of mingled gases, which presses upon the surface of the earth with a gravity equal to that of a solid sphere of lead nearly $6\frac{1}{4}$ miles in diameter rises to an altitude the exact limit of which is still a matter of doubt, but which, from calculations based upon the phenomena of refraction, is usually assumed to be about 45 miles, although more recent observations upon the zodiacal light and meteoric showers, indicate that it may extend to a height of upwards of 200 miles. This voluminous mixture, which in the ancient system of philosophy was considered an elementary body, affords a constant field of study, both in its physical and chemical aspects; and in each of these specific divisions it has received the attention of eminent investigators, who have gradually added to the knowledge we possess of its properties.

As is generally known, the atmosphere is a mechanical mixture of two gases—nitrogen and oxygen—together with minute quantities of carbonic acid, and aqueous vapor, and traces of nitric acid, ammonia, and hydrocarbons. This composition is remarkably uniform. Air from the delta of the Nile, from the arid plains of Egypt, from the icy cliffs of Mount Blanc, from the snow-clad summit of Chimborazo, from an elevation of from 18,000 to 21,000 ft., gathered by means of balloons, and from the lowest levels of deep mines, has been subjected to careful analysis, and but a trifling variation from a uniform composition has been detected. For all practical purposes, atmospheric air may be considered as simply a mixture of nitrogen and oxygen; its other constituents—chiefly derived from local sources—existing as impurities. Of these gases, nitrogen largely preponderates, comprising $\frac{4}{5}$ of its bulk.

Notwithstanding the many causes combining to vitiate the atmosphere, this balance is beautifully maintained. When we take into consideration the fact that at every inspiration we inhale into the lungs a certain proportion of oxygen, which there combines with carbon, and is exhaled as carbonic acid, it is apparent that a heavy draught is being constantly made upon the vitalizing principle of the air, which is replaced by a poisonous impurity. The amount of carbonic acid thus daily generated from the lungs of a single healthy adult is not less than from 33 to 40 oz. When this amount is multiplied by the population of the world, and the product of the respiration of the lower animals added, together with the immense quantities of carbonic acid produced by combustion, putrefaction, and fermentation, it will be observed that vast streams of impurities are being constantly poured into the air and diffused throughout its volume. And yet, with all this pollution, so active are the energies of nature, and so harmoniously are her processes performed, that under the influence of solar rays plants take up the carbonic acid, and by the mysterious operations of their development decompose it into carbon and oxygen, retaining the former to build up their structure, while eliminating the oxygen to once more resume its active vocation in the air.

Nitrogen, which plays so important a role among the elements, was discovered in 1772, by Dr. Rutherford, Professor of Botany in the University of Edinburgh. He demonstrated that air from which oxygen had been abstracted by the respiration of an animal, and the resulting carbonic acid absorbed by lime water, still contained a gas incapable of supporting either respiration or combustion. Lavoisier and Scheele subsequently proved that this gas constituted $\frac{4}{5}$ of the air. The former of these chemists gave it the name azote, from two Greek words signifying privative of life, by which it is still known in France. Chaptal afterwards named it nitrogen, because it enters into the composition of nitre.

The properties of nitrogen gas may be described by a series of negatives. Singularly inert in its habitudes, and capable of directly entering into combination with but few of the other elements under the influence of light or an elevated temperature, its office in the air seems to be simply that of a diluent of oxygen. Some chemists have supposed the atmosphere to be a chemical compound of these two gases; but this opinion is entirely fallacious. The mixture is merely a mechanical one. Oxygen is essential to life, and to every process, either natural or artificial, in which we are interested. Did the atmosphere consist wholly of this gas, or should it occur in much larger proportion than its normal quantity, the effect on animals would be almost equally disastrous, as would result from an undue diminution of its percentage. The processes of life would be stimulated and quickened to an unnatural extent, and this would be followed by a speedy exhaustion and death. Nitrogen, by its negative chemical qualities preserves the physical balance between the elements of the air, and fits it for the admirable functions which, in the all-wise purposes of creation, have been delegated to it.

With hydrogen, nitrogen forms the useful volatile alkali known as ammonia, its name having been derived from that of its chloride—sal ammoniac—which was largely produced by burning camel's dung in the Lybian desert, near the temple of Jupiter Ammon. This important compound was known to the alchemists, having been mentioned by Raymond Lully as early as the 13th century. Traces of ammonia are found in the air, in soils, and in some mineral waters. It is a product of the putrefaction and decay of animal and vegetable tissues, and is largely eliminated from coal during the process of manufacturing illuminating gas. The latter is now the most important source of the ammoniacal salts of commerce. Ammonia is one of the most useful and important reagents in the laboratory of the chemist. In medicine and the arts it is largely employed. In the economy of the household its carbonate is sometimes used in baking, and at the same time it is an appliance of the toilet in the form of "smelling salts." Its sulphate is a constituent of alum, in which form its application to the arts of dyeing and calico printing is very extensive. Its chloride likewise ministers to the requirements of industry, while its nitrate has within a few years become an article of extensive business as a source of nitrous oxide, an anæsthetic which, in minor operations, has proved a boon to thousands of patients.

Of the oxygen compounds of nitrogen, nitric acid and its salts are the most important. This powerful acid is one of the most highly corrosive bodies known. The readiness with which it parts with its oxygen is one of its most valuable features, and leads to its extensive application in the arts as an oxidizing agent; while its salts, which in certain combinations possess this property in a high degree, are endowed by it with an importance which renders them indispensable in every civilized community. So long as war is regarded as the ultimate resort of contending nations, will the salts of nitric acid maintain their prestige as conservators of power. In this aspect they demand a recognition beyond that usually accorded to chemical compounds, and enforce their claims to the attention of statesmen with an urgency which experience has fully justified. As a constituent of gunpowder, nitrate of potassa preëminently asserts its demands upon the requirements of governments; and as other nitrates may be converted into this salt, they all possess a significance which renders their fabrication worthy of grave deliberation.

The phenomenon of combustion is simply a process of rapid oxidation. When this process is accelerated beyond the capabilities furnished by atmospheric oxygen—in other words, when oxygen in a condensed form is furnished to a combustible—it results in deflagration. If the deflagration takes place in a confined space, explosion is the consequence. The proper control and utilization of the pent-up energies of explosive compounds has formed a subject of momentous importance, coexistent, almost, with the progress of civilization; and, as in all of the combinations which experience has proved reliable, nitrogen in union with other elements plays a significant part, a discussion of their origin and properties may not be unprofitable.

Probably the earliest known compound of nitrogen was nitrate of potassa, which was mentioned in the 8th century by Geber as *sal petrae* (rock salt)—whence the term saltpetre; but, of course, in this remote period not the slightest knowledge of its composition was entertained, as this was first determined by Cavendish in 1785. Even prior to this time, saltpetre must have been practically known to the Chinese; for, at the inception of the Christian era, this remarkable people were well acquainted with fireworks, into the composition of which nitrate of potassa largely entered. The peculiar characteristics of this salt eminently adapt it to the manufacture of gunpowder; but before entering into a discussion of its merits, it will be well to inquire into the nature of other nitrogen compounds, and to glance at their relative qualifications.

Nitric acid, according to the heretofore received theories of chemical nomenclature, consists of one equivalent of nitrogen combined with five equivalents of oxygen; or, in percentage, amounts (omitting fractions) of 26 parts of nitrogen with 74 parts of oxygen. As its value in combination consists solely in the amount of available oxygen it will yield, those of its salts having bases of a low combining power would seem best fitted to exhibit its value, for the reason that they furnish a relatively larger proportion of this powerful supporter of combustion. For example, the bases magnesia, lime, and soda, all possess a lower combining power than potassa, the proportions being as 20 : 28 : 31; while potassa possesses the comparatively high equivalent of 47. Thus, while nitrate of magnesia contains nearly 65 per cent. of oxygen; nitrate of lime, 58.53 per cent.; and nitrate of soda 56.47 per cent.—nitrate of potassa contains but 47.52 per cent.; and yet from its physical qualities the latter salt possesses advantages which overcome the higher proportions of oxygen which the others yield. With the single exception of nitrate of potassa, the nitrates above mentioned are too deliquescent in their nature to adapt them for use in the manufacture of gunpowder. Nitrate of potassa, on the contrary, does not abstract moisture from the air; and hence gunpowder made from it may be kept for an indefinite period with its qualities unimpaired.

Although the composition of gunpowder is generally understood, it may be well in this connection to revert to its constituent parts, in order to inquire into the influence its nitrogenous component exerts in its action. The proportions of its three ingredients—charcoal, sulphur, and saltpetre—vary in a trifling degree, as the product may be required for artillery, blasting, or for sporting purposes. Theoretically, the requirements of gunpowder determine that the proportion of its constituents should be one equivalent of saltpetre, one of sulphur, and three of carbon, which, reduced to percentage amounts, would be 74.9 parts of saltpetre, 11.8 parts of sulphur, and 13.3 parts of charcoal. On the ignition of this mixture, nearly 60 per cent. of its solid constituents instantaneously fly to the gaseous state, thereby enormously expanding in bulk—1 volume of the powder becoming suddenly augmented to 296 volumes. Nor is this all; for in the sudden conversion of the carbon into carbonic acid, which is accomplished by the disengagement of the nitrogen and oxygen, and the appropriation of the latter by the carbon, an intense heat is generated, which vastly expands the resulting gases, increasing their bulk to more than 1,500 times the original volume of the powder. The wonderful energy of this explosive may thus be seen at a glance. Before its resistless force potentates have fallen and thrones have tottered; and with a universal recognition of its power, governments have sought to control its sources, and have resorted to all conceivable means to insure its coöperation in their varied schemes of conquest, aggrandizement, or defence.

Of the constituents of gunpowder, charcoal and sulphur are abundant, and may be produced in almost all countries. Saltpetre, however, is a substance whose occurrence in any noteworthy quantity is restricted to limited localities, mostly far remote from those centres where it is needed for use. Of its component parts, potash is produced wherever wood is burned for fuel, and hence a supply of this constituent may be readily obtained; but its nitric acid, which is its ultimate source of power, must be sought for in the few localities in which it exists in the form of nitrates, for by treatment with wood ashes or salts of potassa these nitrates may all be converted into nitrate of potassa —in which form alone, as we have seen, is a nitrogen compound fitted for use as a constituent of gunpowder.

In the provinces of Bahar, Bengal, Allahabad, Agra, and Oude, in India, near the banks of the river Ganges, exists the most remarkable deposit of nitrate of potassa in the world. Extending along the valley of the sacred stream for a distance of several hundred miles, this salt is found as an efflorescence or crust upon the surface of the sandy soil, where it occurs mingled with small quantities of the nitrates of soda and lime. The surface soil is removed and lixiviated in water, and the crude solution evaporated to the point of crystallization, when the small impure prismatic crystals of commercial saltpetre are deposited. In this form it is largely exported, the average annual production being estimated at about 25,000 tons. The British Government wholly controls this source of saltpetre, and for reasons of its own has twice prohibited its exportation —the latter time during the Crimean war —thus suddenly producing a great scarcity, and rapidly enchancing the price of what was already in the market. In China, Ceylon, and other parts of Asia, there are caves and plains where nitrous earth is found ; but they bear no comparison with the remarkable deposit of the valley of the Ganges.

In South America, on the borders of the republics of Peru and Chili, within a few miles of the town of Iquique, there exists a deposit of nitrate of soda—sometimes known as soda saltpetre—which is scarcely less remarkable than the beds of its potash congener of the Ganges. This deposit has been proved to extend for upwards of 150 miles in length, and is from 2 to 3 ft. thick. As it is dug from the ground it consists of upwards of 60 per cent. of nitrate of soda. It undergoes a hurried purification by lixiviation and crystallization, and is then largely exported to this country and Europe, where it is extensively used in the manufacture of nitric and sulphuric acids, as well as in the fabrication of nitrate of potassa. Other deposits of soda saltpetre of considerable extent exist in parts of Brazil. In the United States there are caves in various parts of the West, where nitrous earth abounds, from which saltpetre is manufactured. In Kentucky, Tennessee, and Missouri, considerable attention has been paid to the subject, and under proper management this branch of industry might, perhaps, be prosecuted with reasonable success.

The preparation of nitrate of potassa from nitrate of soda is a very simple art. It was formerly performed by adding equivalent proportions of a solution of nitrate of soda to a boiling solution of the ordinary potash of commerce, when a change of bases resulted, the product being nitrate of potassa on the one hand, and a mixture of carbonate of soda, together with some caustic soda, on the other, as the potash used may have been more or less carbonated. Since the large importation of muriate of potash from the Strassfurt salt mines, this compound, owing to its greater cheapness, has been substituted for commercial potash. In this case the product is nitrate of potassa and chloride of sodium, which latter is sometimes sold as " chemical salt " for fertilizing purposes.

In addition to these sources of nitrates, the natural production of nitrous compounds is imitated by artificial saltpetre plantations, in which advantage is taken of the peculiar results of the decomposition of animal matters. These refuse materials, which contain a varying proportion of nitrogen, in the process of gradual decay generate notable quantities of nitric acid, which combines with lime, potash, or any other available base which may be present. By the addition of wood ashes the whole of these nitrates may be converted into nitrate of potassa. In this manner saltpetre is made in France, Germany, Hungary, and other European countries. The process, however, is a very slow one, and the product small; and in the event of a sudden and unexpected demand, it must be regarded as incapable of furnishing a sufficient supply.

The limitation of natural beds of saltpetre to but few localities, and the extreme slowness with which nitrates may be artificially produced, together with the fact that its natural stores are held by nations which may perhaps in time be hostile to us—these considerations open up grave questions as to our supply in such a contingency as may readily happen. Modern warfare is not decided merely by the relative bravery of contending armies, or the military skill of eminent generals. National power depends much more closely upon the unlimited possession and control of resources indispensable to the prosecution of war and the sustentation of large forces, and chief among these requirements is an exhaustless store of ammunition. As we have seen, we can furnish within our own borders an abundance of all the constituents of gunpowder, with the single exception of its nitrous component. For this essential we are almost wholly dependent upon foreign countries.

We have hitherto referred to gunpowder only as a source of power in war; but in the arts of peace and in the prosecution of daily industry it claims our attention as one of the most efficient appliances ever invented by the skill of man. In the vast engineering works which distinguish modern times from earlier periods of history, explosive compounds have borne a great share of the burden, and have contributed in a ratio beyond that for which credit has been given. In the construction of railroads and canals, in the quarrying of rocks and minerals, in the extraction of ores from their hidden recesses deep in the ground, in the blasting of tunnels and levelling of mountain masses, in the deepening of channels and water-courses, gunpowder has performed its useful functions and asserted its power as one of the most useful energies which has been subdued to our requirements.

Nor is it to gunpowder alone that we are indebted for this great assistance in overcoming the impediments of nature. Other explosives are now extensively used, and in nearly all of them we find nitrogen an essential element. In gun-cotton, which, in the hands of the Austrians, has been successfully applied to artillery; in the newer, but far more terrible compound, nitro-glycerine; in dynamite and dualin, the singularly inert nitrogen plays its peculiar part, and by the very feebleness of its affinities and the ease with which it leaves its fetters and resumes its gaseous state, endows its mixtures with a terrific force, which, properly controlled, has proved of inestimable benefit to civilization. But even these explosives are surpassed in violence by other compounds of nitrogen. The fulminates of silver, mercury, and gold all contain this element, and to its presence is their fearful detonating power ascribed; while, ascending still higher in the scale of violence, we find the climax reached in the action of the chloride, bromide, and iodide of nitrogen. These unstable bodies can be made only in exceedingly limited quantities in the laboratory of the chemist. So readily and with such terrific force do they explode, that they are almost entirely beyond control; and even with a full recognition of what obstacles science has hitherto overcome, it is safe to assert that these compounds can never be subdued to the uses of man.

If we pursue our inquiries into the realms of nature and investigate the composition of the members of the animal and vegetable kingdoms, we shall find nitrogen one of the most important elements entering into the formation of their tissues. The agriculturist practically recognizes this fact by supplying to crops under culture fertilizers in which nitrogenous compounds form a prominent feature. All our important cereals and leguminous plants which constitute staple articles of food in various climes, derive much of their value from this source. Indeed, dietetic materials have been divided by some physiologists into two classes—flesh formers and heat producers. The former division, which builds up and renews our bones, blood, muscles, and tissues, being largely composed of nitrogenous substances; while the latter, which serve by their oxidation to maintain bodily warmth, consist chiefly of starch, oil, gums, etc., into the composition of which nitrogen does not enter. Deprived of nitrogenous food, emasculation would succeed the once vigorous condition of the body, and a rapid declension of vital power would ensue, terminating in certain dissolution.

The nitrogenous remains of the brute creation, which are unfit for food, are made subservient to our uses in a variety of ways; and guided by the teachings of chemistry, which is the great conservator of economy among the sciences, almost every fragment is utilized and turned to a profitable account. Even that which escapes our attention or care, by the revivifying processes of nature, is soon eliminated from its former combinations, and fitted to enter anew into the composition of plants and animals, to again minister to our wants.

In the form of cyanogen and its compounds, nitrogen enters into another series of combinations of great importance in the arts. In the deadly prussic acid, in the golden and ruby crystals of the prussiates of potash, and in the azure pigment known as prussian blue, it is an essential constituent. Again we find it occurring in the beautiful tinctorial products of the aniline series of colors—as mauve, magenta, rosaniline, and their congeners.

The vegetable alkaloids, which in the hands of the skilled physician have so often assuaged pain, removed disease, and brought back the ruddy glow of health to the pallid cheek, invariably contain nitrogen; and so significant a position does this element hold in their composition that from its presence have chemists always started in their speculations upon the constitution of these important bodies. Among this class may be mentioned the deadly poisons, nicotine, strychnine, morphine, brucine, coniine, and the like, whose fearful effects upon the system are frequently invoked by the suicide, and employed by the cowardly assassin.

And thus, in these various mutations, we find the inert nitrogen fulfilling its functions in nature and art. Surrounding us on all sides by its perpetual presence, and yet perceptible to our senses only when wafted in gentle breezes, or in the more forcible aerial currents known as winds; preserving us from the too exhilarating effects of oxygen by toning down, as it were, its stimulating qualities; aiding to build up our bodies, and to repair the wasting muscles and tissues, and furnishing us with delicate pleasures of the table; and again gently lulling us to slumber, and guarding us from pain when the aid of the surgeon must be invoked, we can but gratefully appreciate its mission and recognize its value. In other forms, helping us to fight our battles and to defend our borders from invasion; assisting in our national celebrations in pyrotechnic displays; building our railways and levelling our rugged and precipitous mountain passes; blasting our ores and minerals from their rocky veins; and anon dealing death and destruction by accidental explosions, its mighty power compels respect and claims the homage due to resistless force. Again, in its compounds supplying us with tints rivalling the hues of the rainbow or the glories of the setting sun; furnishing us with costly furs and silks, and woollen raiment of more modest pretensions, ministering to our requirements in the hour of disease by providing remedies indispensable to the medical profession, and yet presenting the suicide with his deadly potion, its influence for good or evil is of no ordinary degree. Although at times indifferent and apparently incapable of positive character, yet among the elements it occupies a position of great importance, fraught with interest to all living beings.

THE GLOBE ENGIRDLED.

From "The Mechanics' Magazine."

In the history of applied science there is nothing more marvellous than the development of Telegraphy. Whether it be by overhead or subterranean land lines or by submarine cables; whether we regard the manufacture of the conducting wires (of which we had a recent notice) or the invention of instruments for transmitting and recording massages,—it is surprising to reflect upon the giant strides that have been taken since the first submarine cable was laid across the English Channel, some 20 or 25 years ago.

It is within a generation that Telegraphy has risen into note as a special science and profession, and at last received due recognition by the establishment of a Society of Telegraph Engineers, as announced by us last week.

At the present moment all that is needed actually to complete a "girdle round the globe," such as Shakespeare only dreamt of, is the connection of the American Pacific Coast and the Islands of Japan; which link in the circumterranean communication is now in contemplation. Mr. Cyrus Field, of Atlantic Cable celebrity, has projected a line from Victoria, the capital of Vancouver's Island, to Hakodadi, in Japan, and from thence to the Russian naval station on the coast of Asia, whence, across the steppes of Siberia, the telegraphic wire penetrates to St. Petersburg, and is united with the European system. This new line, the estimated length of which is 4,370 nautical miles, will touch at Atcha, one of the Aleutian Islands.

The second route projected by Mr. Field, is identical with the first, as far as Atcha; it pursues a more southerly course to Yokohama—a distance from the United States of 4,235 miles. From Yokohama it describes a segment of a circle to Shanghai—a further distance of 1,010 miles. A branch crosses the Island of Niphon and the Japan Sea, and joins the Russian lines at Possiette. A third and last route starts from San Francisco, traverses the North Pacific to Honolulu in the Sandwich Islands, connects this group with Midway Island, and thence to Yokohama—a total distance of 5,573 miles. Making an allowance of 20 per cent. for slack, the length of cable required for the first route is 5,244 miles; for the second, 5,244; for the third, 8,463. Each line is supposed to terminate at Possiette, which is 1,480 miles from Yokohama. It is in contemplation to lay a cable between Honolulu and the Australian Colonies, thereby establishing direct intercourse between Melbourne and San Francisco. This line is thus divided:—San Francisco to Honolulu, 2,093 nautical miles; Honolulu to Fiji Islands, 2,950; Fiji to New Caledonia, 810; New Caledonia to Brisbane, 800—6,653; add 20 per cent. for slack, 1,331; length of cable, 7,984 nautical miles. Brisbane is already connected by land lines with Sydney, Melbourne, and Adelaide; also with Port Darwin on the north coast, from which place a line to Java is under contract for construction. The Dutch colony is now in direct relation with the India and Chinese cables. These being completed, however, it would be vain to imagine that in 40 min. a message would encircle the globe. Allowance must be made for breaks, as the wires are by no means continuous, but for which less than 40 secs. would suffice.

FIELD ARTILLERY.

From "The Engineer."

A report has just been printed by the War Office containing a summary of the proceedings of the Committee on "High-Angle and Vertical Fire from Rifled Howitzers and Mortars," and on "Muzzle-loading Rifled Guns of Large Calibre for Field Service." The report in question is made with reference to the 16-pounder gun, now recommended for the Service by this committee. It would be difficult to name a subject, connected with artillery matters, of greater importance. In the field, whatever may be the value of the work performed by individual batteries, the decisive effects are produced by massing guns; and for this purpose pieces of heavy calibre are retained in reserve, and are kept in hand for the moment when their fire may be brought to bear on an important point with crushing and decisive effect. The 16-pounder, then, is the gun that must strike the telling artillery blows in our future battles. It behooves us to weigh well any decision governing the power and character of such an arm. The report before us commences by relating the preliminary steps that brought the Committee to the final aspect of the question. They were, it seems, informed that "the great object in view was to ascertain and lay down definitely what should be the weight and calibre of the largest class of rifled guns suitable for field service." Certain existing bronze guns—9-pounder smooth bores, of 13 cwt. and 10 cwt.—were placed at the disposal of the Committee, which guns they converted into rifled 20-pounder howitzers;

these gave, as might be expected, unsatisfactory results; 20 lbs. was the minimum weight of projectile which would give good proportions with so large a bore as that of the 9-pounder smooth bore, viz., 4 in., after conversion; and 20 lbs. was too heavy to admit of the required mobility. Then the metal appeared to be too soft. The axis of the trunnions fell below that of the bore, and there was great preponderance in these guns; all these caused difficulties that warranted their condemnation. A proposition was made by Major Palliser to line them, and at the same time to reduce their calibre and improve their proportions; but so much alteration was required that it appeared unlikely that there would be such a saving of expense as to justify the adoption of a patched gun, or a new carriage, in preference to a new gun altogether. The Committee, therefore, recommended the manufacture of 2 guns, of a weight of from $11\frac{1}{2}$ cwt. to 12 cwt., with a preponderance not exceeding 10 lbs.; "that their calibre should be between 3.5 in. and 3.7 in., whichever might be found best suited to a shrapnel shell weighing from 16 lbs. to 17 lbs., and a common shell about 3 calibres in length;" that the rifling should have a uniform pitch of 1 turn in 30 calibres, and that the service charge should be 3 lbs. On the 17th of January, 1871, accordingly, trial was made of a gun, whose weight was 11 cwt. 2 qrs. 21 lbs., its calibre was 3.6 in., and its preponderance 10 lbs. Its shrapnel weighed 16 lbs. $5\frac{3}{4}$oz., and its common shell was 10.25 in. long. It conformed, in fact, with the required conditions, and this gun in all essentials corresponds with that finally recommended for adoption into the service. An important question, however, arose, before this conclusion was arrived at. "The attention of the Committee was drawn to the advantage of a 3.3 in. bore for a 16-pounder gun, for which bore, it was contended, a projectile might be constructed capable of sustaining velocity longer than any other projectile of the same weight"—and we must assume of the 3.6 in. calibre. Comparing the projectiles of the 2 calibres as to their powers of flight, it appeared that, supposing them both to start with an initial velocity of 1,350ft., their remaining velocities at 1,000 yards would be 1,052 ft. per second for the smaller, and 1,020 for the larger calibre; and at 2,000 yards range their respective velocities would be 920 ft. and 889 ft. per second. So it was agreed to make a trial of a gun of 3.3 in. calibre as it was found that the useful capacity of the shrapnel shell would not be materially affected by the decrease of diameter, and the twist of 1 in 25 was given to this gun.

The two guns then "were tried at Shoeburyness, both having the same length of bore, and both being rear vented. It was found that the reduced calibre gave an increase in length of 2 in. to the cartridge, and interfered with the rapidity of ignition of the powder, so that the initial velocity of the 3.3 in. gun was only 1,307 ft., against 1,358 ft. obtained with the 3.6 in. gun. Fired at 2 deg. of elevation, the smaller calibre ranged 1,057 yards, the larger 1,187. At 9 deg., the smaller 2,172, and the larger 2,228; but fired at 10 deg. elevation the projectile of the former gun had succeeded in overtaking that of the latter, obtaining at this elevation a range of 3,619, against 3,596." The powder employed throughout was that known as service R.L.G. The accuracy of the two guns was about the same. The 3.6 in. bore was therefore recommended.

This all seems so sound, so reasonable, that the conclusion appears almost foregone before the end of the trial. Nevertheless, after all the experiments that have been made during the last few years on the resistance experienced by projectiles in flight, the apparent insignificance in the effect of the difference of calibre between 3.3 in. and 3.6 in. seems strange, and calls for close scrutiny. The weights of the shells are equal, and the resistances are in the proportion of 1,089 against 1,296 at any given velocity. In examining the report more carefully, the first question that arises is, "Why do the Committee *estimate by comparative velocities* at various points, and then, instead of reporting as to this, change their ground, and give the *ranges due to various elevations?*" This seems to obscure rather than to clear up the matter. "It was contended," they say, "that the smaller bore was capable of sustaining its velocity longer." The contender was, at all events, right so far, for it is absolutely impossible that this could fail to be true. The Committee, however, urge that the length of the cartridge of the smaller bore prevented rapid ignition of the powder, so that the projectile started with a lower velocity. Venting at the rear was all against the small bore; but assuming this was necessary, why is no more said of velocity? It is hard enough to be handicapped, but then to have attention called to the relative positions at starting, as though it were the finish, is indeed adding insult to injury. Having noticed the velocity that told against the small bore, not one word more is said on the subject; the key is changed, and we only hear of ranges due to various elevations, as if the contender had said that the smaller calibre would have a higher *initial* velocity.

But it may be asked, if two projectiles leave their guns at the same angle of elevation, does it not follow that the one that obtains the greatest range has, on the whole, travelled the fastest, since they both must fall at the same pace? Certainly it has travelled the fastest on the whole, but here lies the pith of the question. Is it the object that the shell should travel as fast as possible, or that *it should hit as hard as possible?* It may be that the 3.6 in. shell starting faster is not "overtaken"—this seems to be the Committee's conception—by the shell of smaller calibre, but if the latter has *commenced to overtake it*, if, in fact, though still behind it on its path, its velocity is greater, it strikes a harder blow, the weight of the 2 shells being equal. Surely 2 or 3 in. in the height of the trajectory can hardly make up for this. If we accept, then, the initial velocity furnished by the Committee themselves, will our readers believe—calculating by means of the tables drawn up by Professor Bashforth—it appears, even at the end of a 1,000 yards range that the remaining velocities stand 1,031 ft. per second for the smaller calibre, against 1,020 ft. for the larger? That is, the former shell has done what was "contended"—it has sustained its velocity so much better than its rival that, even starting at a considerable disadvantage, it is already moving the faster of the two, and will strike the harder blow. It has, in fact, commenced to overtake the larger shell. At 1,500 yards the respective velocities are 958 ft. against 939 ft.; at 2,000 yards they are 902 ft. against 877 ft.; and at 2,300 yards, 872 ft. against 844 ft.; the shell of smaller calibre continually increasing in power as compared with the other. But the Committee may say, it is still behind it. Let us try to look at the matter, then, from this point of view. Is it the great object to get in the shot as *quickly* as possible? If two men fight, one may be the stronger, but his adversary may get his blow in first; he may, in short, give him a black eye before he has time to strike. We find the shell of larger calibre may, at a certain range, perhaps strike the object .02 of a second sooner than its rival, and its path may be an inch or 2 lower in the air. If this is the argument, we ought indeed to insist on our gunners being trained to drill with rapidity. If the decimal part of a second in the *date of arrival* of a projectile is of such pre-eminent importance, it is sad to reflect how many times .02 of a second may be lost by a cough, almost by a wink.

To return to the trajectories of the shells. It appears that at 3,000 yards and over, the tables are turned, for here, we are informed, the one of smaller calibre *has "overtaken"* its rival, and won the race. No great stress seems laid on this circumstance, the range being a long one, only 500 yards short of 2 miles. But we must recollect that we are discussing reserve artillery, in which range and power at long ranges are of primary consequence. The fact is, we are now coming to the most important ground on which the smaller calibre might claim that advantage. Reserve artillery strike the decisive blows in battle; in almost all cases the guns are brought up and called upon to open fire, in the teeth of, at all events, some pieces already in action. This is a service that may be one of great difficulty and danger. General Okouneff, the most enthusiastic advocate for massing guns, considers that it is impossible for batteries to come into action under the fire of a really powerful artillery with a hope of success. Surely under these circumstances it is difficult to insist too strongly on reserve artillery having a superiority in range, and in power at long ranges, over light or ordinary field batteries. Suppose the order given to bring up the reserve guns for a decisive movement. Every 50 yards the batteries advance they become subject to a great augmentation of casualties, not only because during such an advance they are exposed, and are liable to be crippled or checked, but because they are coming under a fire which is growing each moment more powerful, and which, as yet, they have not answered ; because they may be traversing ground over which the enemy have been, as it were, practising, and of which they know the range of every spot, and because every 50 yards they have to move increases the difficulty of opening fire simultaneously, and generally necessitates the batteries closing on each other laterally. Here, then, the stand is to be made. The 16-pounder, of 3.6 in. calibre, can hardly be said to be superior in range to the field batteries already in the service ; nay, it remains to be shown that it is at all superior in this respect to the Armstrong 12-pounder, which has so long been our field battery gun, for though the projectile of the 3.6 in. gun has a higher initial velocity, the resistance of the air acts with more power on it, so that the 12-pounder may even have the greater range at the higher angles of elevation.

It is curious, however, that the Committee have conceded one advantage that might have been urged in favor of the 3.6 in. bore as compared with the 3.3 in. bore viz., that the shell must have the superiority in interior capacity, from the fact that it is more compact in its form than its mere elongated rival. This ought to tell both on the number of bullets contained in its shrapnel and in the bursting charge of its common shell. It seems, however, from the report, that this is not very manifest, probably from the fact that the bullets happen to be of a size fitting with less loss of space in the shell of smaller calibre. On the other hand, we cannot but believe that had any extended trial been made at long ranges, the smaller calibre would have proved its superiority in accuracy in flight.

Altogether, we would express a hope that, since the 3.3 in. gun has achieved what was contended for it, that since it has proved itself superior in all respects at long ranges, and superior in striking velocity at 1,000 yards and over, that it will not be condemned because at the shorter ranges it has a "date of arrival" of a small decimal part of a second greater than its rival, or because its trajectory is, under these circumstances, 2 in. or 3 in. higher.

MR. WHELPLEY'S THEORY OF GRAVITATION OR CONSTANT FORCE.

By W. L. MARCY.

The assumption of Jas. D. Whelpley in the December No. that the distance fallen through is proportional to the square of the actuating force is erroneous. Whelpley's error is in regarding, with different forces, the spaces fallen through, equal when the velocities attained are equal.

Thus, if 1 oz. falls free, it descends 16 ft. in a sec., but distributed over 16 oz. as in the Atwood machine, there is a descent of 1 ft. in a sec.: but it does not follow that the 16 oz. falling free with an actuating force 16 times as great as when urged by 1 oz. will in $\frac{1}{16}$ of a sec. fall 1 ft., for, as recognized in the "Essay," the distance of the fall is proportional to the time squared; hence, instead of 1 ft. in the $\frac{1}{16}$ of a sec. it is $(\frac{1}{16})^2 \times 16 = \frac{1}{16}$ of a ft., although in both cases the velocity is the same at the end of the sec. with 1 oz. force and $\frac{1}{16}$ of a sec. with the 16 oz. force, but the distances fallen through are inversely as the forces. Again, the 1 oz. force will, at the end of 4 sec. fall $(4^2 \times 1)$ 16 ft., giving a resulting velocity of 8 ft. instead of 32, for, the velocity in all cases varies as the time multiplied into the actuating force.

In Whelpley's example, a body actuated by one unit of force falls 1 ft. in a sec., acquiring a velocity of 2 ft. per sec. Now these units of force will give the same velocity in $\frac{1}{3}$ of a sec., but the fall is $\frac{1}{3}$ of a ft. instead of 1 ft.; here lies the error by which he arrives at a result of 9 ft. in a sec. which should have been only 3 ft. in that time.

The error of the assumption can be readily shown theoretically by regarding the constant actuating force as so many regular impulses infinite in number, describing spaces in arithmetical progression. Calling the first space d, we have from the equality of the impulses the series $a+2a+3a+\ldots .na$(V) in which the sum expresses the distance of the fall and the last term the resulting velocity. By the known laws of such series the square of the last term, *nf* (equivalent to the velocity) or of the number of terms, *n* (equivalent to the time), is proportional to the sum or distance of the fall, which accords with experience. Furthermore, we infer from the same series, that the last term or velocity may be equal, but the sum or distance fallen through unequal, for the sum of the series for a given final term (V) is inversely as the impulse *d*, or actuating force.

STRAINS ON ARCHES.

From "Engineering."

The author, after adverting to his method* of constructing a curve of equilibrium for an arch unequally loaded with continuous or discontinuous weights, or under oblique pressures, proceeded to apply it to the determination of the stresses on rigid arches and other curved structures.

As the consideration of an arch of masonry was more simple than that of a rigid arch, a preliminary illustration was given by an examination of the Pont-y-tu-Prydd, an arch of small stability, with the peculiarity that its spandrels were constructed with cylindrical openings. The effect of these openings was described. To show the nature of the change of the curve of equilibrium by oblique pressure of the backing, this curve was drawn on the supposition that the backing was a perfect fluid, pressing at right angles to the back of the arch. The action of a passing load in increasing the stress upon the masonry was also examined.

The stresses of a rigid arch had hitherto been a subject of considerable difficulty, owing to the intricate nature of the mathematical analysis it was necessary to employ, and the labor of applying formulæ to trace the variation of stress from point to point was considerable. Still, before the transverse sections of arch ribs could be proportioned to the stresses coming upon them, a knowledge of this variation was indispensable.

The main object of the paper was to show that the stresses at every point of an arch rib could be determined by a diagram, and that some questions, such as where the form of the rib was neither circular nor parabolic, and when the pressure was oblique, which would be almost intractable by analysis, could be readily solved. The curve of equilibrium being the locus of the resultant of all the outward forces, the bending moment was the pressure in the direction of the curve multiplied by the perpendicular upon the tangent. The curve having been determined, the stress caused by the bending moment could be ascertained, and this, added to the uniform compression, was the total stress at any point. By shifting vertically the positions of the points of the curve at the crown and springing, the stress could be indefinitely varied, and the curve could be made to satisfy the conditions of the rigid arch or invariable span, or the rigid arch with the ends fixed.

These conditions were then investigated and gave the following results. The neutral line of the arch rib having been divided into equal parts, and the bending moments at each of these parts obtained from the curve of equilibrium, when the ends were fixed the sum of all the bending moments had to be made equal to zero; when the rib was of invariable span, the sum of the bending moments, each multiplied by the vertical ordinate of the point to which it corresponded, had to be made equal to zero; and when the ends were fixed and the rib of invariable span, the above conditions had both to be satisfied. When the section of the rib changed from point to point, each bending moment was to be divided by the moment of inertia of the cross section corresponding to it, before entering it in the summation. It was then remarked that where the curve of equilibrium touched the surface of the rib, the compressive stress was doubled, trebled, or quadrupled, according as the section was **I** or box-shaped, tubular, or of the form of a solid rectangle. For vertical forces only, the bending moment at any point was equal

* Abstract of a paper read before the Institution of Civil Engineers, London, by Mr. Wm. Bell, C. E.,

to the horizontal thrust multiplied by the length of the vertical line between the curve of the rib and the curve of equilibrium.

A mathematical investigation was entered into for a circular rib, considered as a voussoir arch, or rigid arch with the ends fixed, in a similar manner to Mr. Airy's treatment of the circular rib of invariable span. It was shown that the stresses could be equally well ascertained by diagram as by mathematical investigation. When a moving load was the only force acting on an arch rib, the curve of equilibrium was two straight lines, meeting in an apex vertically above the load. As the load moved, the locus of this apex depended on the condition of the rib, as to whether it was rigid, or in the state of a voussoir arch. The action of a uniformly distributed load was then examined, and the circular rib compared with the parabolic. It was remarked that a straight or curved girder might be considered as an arch of any rise, but without horizontal thrust, and it was shown that, by drawing any curve of equilibrium for the weights, continuous or discontinuous, acting on the girder, considering it as an arch, the stress at any point was the horizontal thrust multiplied by the vertical ordinate.

The action of oblique forces was then entered into, and the case of the curved gates of the Victoria Docks was examined.

The stresses on the elliptical caissons used in the foundation of the Thames Embankment were next ascertained by construction. It appeared that when the eccentricity of an ellipse under normal pressure was small, the curve of equilibrium was nearly a circle, whose radius was the mean between the length of the major and minor semi-axes of the ellipse; and that if a boiler, which was an arch in tension instead of in compression, were not truly cylindrical there would be considerable transverse in addition to the tangential stress, and if the deviation from an exact circle were greatest at the riveted joints, the stress would be greatest at the weakest parts. It was then remarked that at an ordinary lap joint, or at a part where the deviation of form amounted only to half the thickness of the plating, the stress at the surface of the iron was four times that due to the uniform pressure of the steam. This result, which showed how greatly a boiler might be weakened by an imperfection of form too slight to be detected by the eye, was not, in the author's opinion, generally known. There could be little doubt that incorrectness of form, the evidence of which was destroyed when a boiler exploded, was one of the chief causes, and hitherto an unsuspected cause, of many of the boiler explosions which occurred from time to time throughout the country.

The last example chosen was the somewhat complex case of the roof of the St. Pancras Station, Midland Railway. The form of the rib differed from the circle and parabola, the section varied to some extent near the springing, and as the action of the wind on the roof was considered, the question was also one of oblique forces. The curves of equilibrium for the roof, acted on only by its own weight, were first drawn. For the actual condition of the rib, namely, that of a rigid arch with the ends fixed, the curve was contained everywhere within the depth of the rib. For a pressure of wind of 40 lbs. per sq. ft., the curve showed two maximum stresses of 4.08 tons and 4.14 tons per sq. in.

The arch rib had been treated as of invariable span, but real or virtual alterations of span might be caused by changes of temperature, a yielding of the abutments, and the compressibility of the arch rib itself. It became then an important practical question to determine, for wrought-iron arches, how much the stresses might be altered by a small alteration of the span. The method of ascertaining this generally was then described, and it was found that a wrought-iron rib of 200 ft. span, 20 ft. rise, of an I or box-shaped section, and loaded uniformly, might have the stress at the crown increased from 4 tons to $6\frac{1}{4}$ tons per sq. in. This would happen if the abutments each yielded $\frac{1}{2}$ in. under the thrust, and the temperature were reduced 60 deg. below that at which the parts of the rib were put together. This result included the stress caused by the compressibility of the iron.

In order to draw the elastic curve of the rib, it was then shown how to find the displacements of the different points, by change of temperature, compressibility of the metal, and action of the bending moment. The deflection of the crown was the alteration of the rise of the rib as found by this process. Applying it to the case of the rib of the St. Pancras Station roof, the deflection of the crown was found to be .2 in., while observation had given from $\frac{3}{16}$ to $\frac{1}{4}$ in., so that the agreement of calculation with observation was very close.

The author proposed to measure stresses by direct observation of the extension or compression of a small length of the material of a structure. For a stress of $\frac{1}{5}$ ton per sq. in., the extension of a length of 50 in. of wrought iron was $\frac{1}{1000}$ of an inch, which, if magnified 50 times, would be read as $\frac{1}{20}$ of an inch by the eye. During the testing of a structure, two microscopes, magnifying 50 diameters, with scales in their eye pieces, fixed about 50 in. apart, would measure stresses of $\frac{1}{5}$ of a ton per sq. in. in the most direct manner, and the stresses could be measured at the critical points of a structure.

The author thought that this method of observation might even be useful in another way; if, as was probable, inferior kinds of wrought iron approached to cast iron in the scale of their extensibility under moderate stresses. By taking an observation the stress could be accurately determined by calculation, the quality of the iron which had been used in a structure might be ascertained.

HEATING FEED-WATER.

From "The Engineer."

Much ingenuity has been exhibited by numerous inventors in designing apparatus for heating feed-water, but an examination of most of the schemes proposed for effecting this purpose will prove that a great deal of ignorance exists as to the conditions to be fulfilled before success in the highest sense of the word can be commanded. The general principles involved are very simple. A pound of steam at atmospheric pressure, 14.68757 lbs. on the sq. in., the barometer standing at 29.9218 in., and the temperature being 212 deg., contains 1146.6 units of heat, each unit representing the quantity of heat required to raise 1 lb of water 1 deg. Fahr. Any feed-heating apparatus worked by the exhaust steam from the engine can only raise the feed-water to the temperature proper to the barometric pressure at the time being, provided the engine is of the non-condensing class. This temperature is universally taken for convenience as 212 deg. If the ordinary temperature of feed-water were zero, then the whole advantage that could be derived from a heating apparatus would be represented by $\frac{1146.6}{212} = 5.408$, or 17.54 per cent. But it is a physical impossibility to have feed-water at zero, and we have given the preceding figures to show that the maximum theoretical saving to be effected by raising the temperature to 212 deg. is 17.54 per cent. The normal temperature of feed-water in Great Britain may be taken at 57 deg., and this temperature must be used, consequently, as the basis of any calculations intended to determine the maximum economical result to be expected from a feed-heater. Deducting 57 deg. from 212 deg. we have 155 deg. The best feed-heater, therefore, working by waste steam, can save but 155 units of heat out of 1146.6, or 13.4 per cent. We have heard it urged by men who ought to know better, that, although this may be true of a boiler working at or about atmospheric pressure —much as Watt's earlier engines did—it is not true of a boiler working at, say, 50 lbs. on the sq. in., because the whole heat contained in 1 lb. of steam of that pressure is taken to be 915.58 only; and that, as a consequence, the calculation stands $\frac{915.68}{212} = 23$ per cent. But these gentlemen forget that the water has to be heated after it enters the boiler by the difference between 212 deg. and 251 deg. The total number of units of heat in 1 lb. of steam of a total pressure of 50 lbs. on the sq. in. is, in fact, 1167.99 deg., so that the saving effected by the use of a feed-water heater is actually reduced as the boiler pressure increases. It is not our purpose here to describe minutely specific forms of heating apparatus, but to deal with the principles on which they operate; and we shall consequently do no more than allude to the fact that the simplest, and therefore best, way to heat feed-water, when a non-condensing engine is used, consists in blowing a portion of the waste steam back into the tank from which the feed-pump draws. If this tank is suitably arranged, and the influx of cold water is constantly maintained at one end while the feed-pump draws from the other at a higher level, no difficulty will be experienced in raising the temperature very nearly to the boiling point. The excessive simplicity of such an apparatus is no small recommendation to its use; and we find this principle now adopted by nearly all makers of portable engines—a hose being led back from the exhaust pipe to the water bucket or tank. By this simple device some 8 per cent. or 10 per cent. of the fuel is usually saved.

We have now to deal with a totally different class of feed-heaters—to wit, those used with condensing engines. The feed-water drawn from hot wells usually has a temperature of 100 deg. to 120 deg.—say, 100 deg., and therefore the saving to be effected by raising the temperature to 212 deg.—as has been proposed by making the feed-water circulate round a long eduction pipe extending from the valve chest to the condenser—could only amount to about 9.7 per cent., even if the temperature of the exhaust steam was that proper to the terminal pressure of the cylinder, which it is not, as the instant the exhaust port is opened it falls in well made engines to the temperature proper to the condenser, or nearly so. Feed-heaters, used in connection with condensing engines, always operate, therefore, through the agency of the waste heat passing from the boiler flues; and it is very difficult, for reasons which we shall now explain, to contrive a really satisfactory heater operating in this way. We have found by experiment that in a good Cornish boiler the gases at the end of the flue, when just leaving the boiler, had an average temperature of 400 deg., the boiler pressure being 50 lbs. above the atmosphere, corresponding to a temperature of 297 deg. Fahr., and this may, within certain limits, be taken as representing good stationary engine practice, when the boilers are properly set and the draught is not forced. Now, in round numbers, we may assume that to bring the feed-water to the temperature of that in the boiler $\frac{1}{5}$ of the whole quantity of heat required to convert each pound of water into steam must be supplied in the heater. If the heater were as efficient, foot for foot, as the boiler, it would follow that it must even then have one-fifth of the whole heating surface of the boiler. The efficiency of any given area of heating surface depends, for one thing, on the difference between the temperatures at opposite sides of the plates, and we think it quite unnecessary to enter into any calculations to prove that the efficiency of a square foot of boiler surface must be very much greater than a square foot of heating surface. This being true, it follows that the heater, to be efficient, must have much more than one-fifth of the surface of the boiler; and if this fact was generally borne in mind we should hear less than we do of the extravagant claims put forward by some makers of heating apparatus, who assert that they can save 20 and even 25 per cent. of fuel by the aid of heaters which do not present one-twentieth of the heating surface of the boiler. It is true that some boilers are so badly proportioned, or so improperly set, or fired so hard, that an immense amount of heat is wasted up the chimney, and in such cases even a small heater will do good, and probably save much fuel. But with properly set and designed boilers the heating apparatus must present a very large surface, certainly not less than $\frac{1}{4}$ that in the boiler, if the feed is to be raised much above 212 deg.; but any heater so constructed that it will take up from waste gas, already lowered to a temperature of 400 or 450 deg., enough heat to raise the temperature of the feed to that of the boiler, will effect a very considerable saving. Let us say, for example, that the boiler temperature is 300 deg., corresponding to a total pressure of 67 lbs.; then the saving effected by heating the feed-water to 300 deg., instead of injecting it at 57 deg., will be represented by $\frac{1173.4}{234} = 4.82$, or 20.7 per cent.

The moment we attempt to construct such an apparatus we find ourselves beset with troubles. In order to obtain enough surface within a moderate space, the heater must consist of some arrangement by which the water is cut up into filaments or streams. Therefore, all these heaters, or "Fuel Economizers" as they are sometimes called, consist of some arrangement of tubes, vertical, horizontal, spiral, or inclined. These tubes, and the parts connected with them, must be competent to withstand the boiler pressure, and this they can be made to do without much difficulty. The great obstacle to their use, however, lies in the fact that they cannot be kept clean without special and more or less complex devices. It is easy enough to get rid of the soot which is freely deposited on the outside of the tubes, and various arrangements of continuously working wire brushes, scrapers, etc., have been patented for this purpose, some of which are in use ; but it is next to impossible to get rid of the deposit within the tubes.

The salts of lime and magnesia, held in solution in most waters, are freely thrown down the moment the water is heated above 212 deg., and the consequence is that the pipes rapidly become furred up and inoperative. If they remain sufficiently open to suffer the feed-water to pass through them, it is only because the incrustation is so thick that the water is no longer made hot enough to throw down any deposit.

It must not be forgotten, however, that this very difficulty may be made to work for good. If the deposit takes place in the heater, then it cannot take place in the boiler. What is wanted is a heater, to be used in connection with stationary boilers, which will work as a separator as well, from which every particle of deposit can be easily removed from week to week. Such an apparatus could not fail to be popular in the highest degree, and we believe that it can be produced. In its production, however, lies a neat problem, which we beg to commend to the attention of our readers.

TRAMWAYS AND THEIR STRUCTURE, VEHICLES, HAULAGE, AND USES.*

By W. BRIDGES ADAMS, Esq.

From "Journal of the Society of Arts."

It is now approaching a period of two years since I read in this room a paper on tramways, endeavoring to foreshadow therein the shortcomings of their proposed system, and pointing out the requirements needed. The desirability of their becoming State and municipal property was shown, together with misgivings as to any State origination, and the possibility that private companies, in the then condition of commercial ethics and governmental perceptions, would, on the whole, be a necessity, and might induce the smallest amount of waste with the greatest profit to both the community and the companies.

So far, the tramways have now been delivered over to companies, trammelled with conditions which will probably end in arbitrations, if at some future time it be found that the disputes between companies involve public inconvenience and inefficient service. As a commercial question, it is quite clear that directors must study the largest profit for their shareholders, and that they will only give in return for it as much service to the public as will prevent traffic from falling off. If a given sum is to be made annually, it will be less trouble to obtain it by a small traffic than by a large one, where no competition exists.

The tramways are popular, and, if we analyze the sources of their popularity, we find them to be threefold. First, greatly increased space for sitting and moving in the vehicles ; secondly, a greater freedom from oscillation; thirdly, the larger number of passengers provided for—preventing disappointment in getting places. But, to set against these, there is the great waste and cost of haulage, not lessened but increased by the substitution of the rail for the pavement. The effect that should arise from the more even surface is neutralized by the grooves in which the wheel flanges travel; and the total resistance to traction is double that of the ordinary railway, on which the flanges of the wheels bear against only one surface with lateral freedom, while on the tram

* A paper read before the Society of Arts.

they bear on two surfaces, and act almost as a constant break, as may be verified by the sound while riding, and the incessant vibration while in motion. There is no doubt that the ordinary omnibus, with its flexible construction, runs far more freely on the stones as regards traction, than does the tramway car on the rails; and when we come to the modern asphalt surface, which gets rid of the omnibus oscillation, the ease of movement reduces the resistance to traction nearly to the minimum. Were the interior of the omnibus as convenient as the tramway car, there is no doubt that it would be preferred.

But the rail has an advantage which the asphalt has not—automatic guidance. It would be exceedingly difficult to steer an omnibus as long as a tramway car in sinuous courses without involving constant collisions. And, on the other hand, the tramway car, as at present constructed, has the disadvantage of not being able to leave the track when needed. It is helpless when off the rails, and constantly tends to run off when on curves, as may be seen in the process of placing the horses at an angle of 45 deg. with the rails, in trying to keep it on.

Let us begin at the beginning. Tramways are, or should be, supplementary railways, not intended for high speeds, but filling in the links and breaks which impede free transit, and adapted for moderate speeds. Obviously, the road and street surfaces are the best adapted for their application. Upon all roads, the best and cheapest mode of transit is the first consideration. Beginning with our own feet and legs as the means of locomotion, we transferred our heavier loads to the legs of quadrupeds, till we discovered that the power of the quadrupeds could be used most economically in the haulage of wheeled vehicles, and that necessitated firm roads, and the absence of firm roads gave rise to the plank or timber tramway, gradually supplemented by the iron tram of the earlier times. As the iron tram, in its improved condition, permitted heavier loads, it was soon found that steam power was far more economical and capable of far greater development and utility than horse-flesh.

Of all the sources of nuisance in transit through towns and along roads, horses are the worst. It is the dirt of the horses that makes them slip on asphalt as well as on stones, though the joints in the stones limit the amount of slip; and the contrivance of boys to pick up the dirt as it falls, is by no means satisfactory, albeit more cleanly. It is one of the many proofs of the force of habit, that we persist in the use of draught horses when the necessity for them ceases. If there be one advantage more than another in the use of tramways, it is to be found in their applicability to the use of steam as a tractive force. It is imagined that there must be an antagonism between a steam engine and a horse, like a clan feud, to go on forever, the engine being the frightener and the horse the frightened. Now, an engine may run away, as in the case of the road roller in Pall-mall, tampered with by the boys, but it is always amenable to the turn of a handle, if the driver has wit enough to guide it; but the horse may take the bit between his teeth, in a fit of obstinacy beyond control; and even staid, respectable brewers' horses are not superior to occasional frights. Upon the whole, the horse is more mischievous than the steam engine, eight times as costly, and far more dirty. If the legislature would look at the question fairly, giving the engine its due, as they have given horses more than their due, no long time would elapse ere we should behold the extinction of horses in our cities as instruments of drudgery by a similar process to that taking place on farms.

On a well laid street, with a sufficient depth of solid concrete, and a surface of elastic asphalt, there would be no difficulty in applying light traction engines, always subject to the condition of steerage by hand. But to form general road surfaces in this mode would be too costly, unless in cases of a large remunerative traffic. A branch line will not bear the same outlay as a main line. Of the value of the general surface of asphalt there can be no doubt, in its freedom from blows, and noise, and dirt, other than those of the horses; but it can only be adapted for comparatively slow traffic, unless with automatic guidance.

We must, therefore, come to the rail, not necessarily in all cases, for it would be a disadvantage in narrow, crowded streets, unless the vehicles were adapted to leave the rail when needed; but for the larger and general purposes of suburban transit we possess nothing, in our present state of knowledge, comparable to the wrought-iron rail, as a smooth, even, tough, and unbreakable substance. If we are to attain this condition, we must resort to some mechanical process for obtaining a really permanent way, in the employment of our iron.

We must have such a mode of construction as will permit the laying the rails, when needed, in sharp curves, as sharp as 35 ft. radius, in order to take advantage of street corners and narrow streets as easily as the existing horse omnibuses. We must also so amalgamate the rails with the road surface that they will mutually support each other, and prevent separate sinking or wear. And as rails can only be made in short lengths, the joints must be so constructed as to make them equivalent in strength to the solid portions of the rails. Now let us examine the existing structure.

A pair of timbers, some 21 ft., in length, 6 in. in depth, and 4 in. in width, are laid in trenches in the road, bedded on concrete, which may or may not be solid. To keep these timbers to gauge, a pair of iron castings or saddles are made to clip each timber. Into these castings a dovetailed iron bar is made to drop, keeping these timbers to a specific width. The space between and outside the timbers is packed with paving stones or other material, to form the road surface, and enclose the rails which are flat bars 4 in. wide and $1\frac{1}{2}$ in. in depth, a groove being rolled in their surface 1 in. in width and $\frac{3}{4}$ in. in depth, leaving an interior rib 1 in. in width, and an outer rib 2 in. in width, for the wheels to run on. The inner rib is notched on the surface, on the supposition that it will prevent horses from slipping, though the notches are below the general surface. A plate of iron $\frac{1}{2}$ in. thick by 4 in. wide, is laid under the joints of the abutting rails, and iron spikes are driven into the timber, through the rail grooves, to hold them down and keep them in position.

It must evidently be a very difficult thing to lay such rails into sharp curves. The rails may doubtless be bent laterally, but the timber will maintain its right of warping, according to its structure and growth, in any direction, unless used in very short lengths, resisted, doubtless, by the paving horizontally, but not vertically. But in the act of paving, it is quite practicable and common, to burst the cast-iron chairs by too tight ramming, in which case the gauge becomes irregular. The load on each small wheel of the vehicle is close upon $1\frac{1}{2}$ tons when fully loaded, and if the timber springs up and down, a constant battering of the concrete must take place below. If the paving sinks irregularly, the rail projects above it and is exposed to the blows of crossing vehicles ; the rails are subject to bend vertically between the timber and the iron-joint plates, and the result is a constant rise and fall of the joints ; and the verification of Mr. Haywood's remark, that "the advent of tramways is always accompanied by a condition of bad paving," is indicated by the men constantly employed in the "maintenance of way."

As yet, the tramways are only passing through what may be termed their "baby disorders," but which will yet grow up into chronic disease, only to be remedied by the process of removal at no distant date. They are in a condition of permanent "rickets.

We come now to the vehicles. Were they fixtures, nothing could be better. They are roomy, well seated, capable of good ventilation, convenient in access and exit, and accommodate a large number of passengers. But when moving, the structure is found to be radically vicious. To move at all along the inequalities and curves of the rails with 4 wheel flanges fitting too closely in the iron grooves, enforces the shortening of the wheel base to the utmost. The vehicle is, with its projecting entrances, 24 ft. in length, and the axles are less than 6 ft. apart. If, therefore, efficient springs were used, the result would be great oscillation, far in excess of that experienced in ordinary omnibuses, and so great as to be unbearable. To counteract this, blocks of india-rubber on the axle-boxes are substituted for springs, in which the motion is very small vertically, and *nil* laterally. Oscillation is thus removed, at the cost of incessant, sharp vibration, with a constant grinding noise, and a quick jump of the wheels when they pass over a pebble in the rail groove. Any observant passenger will be familiar with this. Side-yield to obstacles there is none, and the wear of the flanges and grooves, and disturbance of the rails in their sites, is incessant. Where curves are necessary, absolutely the only mode of keeping the vehicles on the rails is to set the horses at an angle, pressing the wheels inward towards the centre of the curve. To allow the flanges anything like freedom would require a groove upwards of 3 in. in width, and correspondingly wide tires. An omnibus, with its wheels all free, rolls; the tramway vehicle, with its wheels all fast on the axles, and of very small diameter, and its axles always parallel to each other, can scarcely roll at all; it can only be a sledge during a large proportion of the movement, and the effect on the horses tells the tale.

In seeking for improvement on the existing tramway, an obvious advantage would be gained by placing the greatest width of the rail vertical, if the existing form permitted any mode of fastening it, as we should then get the greatest strength in the direction of the load borne on it. The quantity of metal in it is quite sufficient to obtain a good form, wholly independent of timber sleepers and fastenings. It should be a deep rail, with a wide upper table, to suspend it from the surface, and a lower table, to key it into the road, and elastic fishes bolted at the side channels at the joints, forming each line of rails into a continuous bar, equally strong throughout. The best form for the rail top would be an open shallow channel with splayed edges, not needing more than a quarter of an inch in depth in the centre, and dispensing with flanges to the wheels, which would thus run as easily as cab and omnibus wheels run in the iron side gutters of the streets, and would not run out without being purposely drawn out, but could with great advantage turn out when required. Such rails, with the heads 4 in. wide and the stems 6 in. in depth, would form 2 backbones to the road, in the form of iron girders, preserving an even surface, and demonstrating that bad paving is not a necessary accompaniment of a tramway, but only a consequence of imperfect structure. In laying down such rails, the simple plan is to connect each pair of bars to a pair of cross timbers at their upper surface, as a temporary gauge, which timbers suspend the rails at the right level in trenches dug out sufficiently wide and deep, to run in, first, a solid mass of concrete, forming a single block, and on that $1\frac{1}{2}$ in. of asphalt, an elastic and tough bedding, without brittleness or tendency to crumble away, as do hard cements. Thus, the rails being solidly fixed, require no tie-bars, which may be dispensed with. A pair of rails being thus fixed, a second pair are connected to the joints by the fishes, and the temporary timber bars then moved on, to repeat the process. When curves are needed, the rails are bent laterally by the machine, either at the works or on the spot, and there would be no warp or tendency to change of form, and no points or crossings would be needed, for any vehicle would be enabled to pass in or out of the shallow channel.

The only objection to such a rail has arisen from companies, and it is a very valid one from their point of view, viz., that such a rail would offer great facilities for use by the proprietors of omnibuses, cabs, and other vehicles, who have contributed nothing to the cost of the rails. But the facility of making communications from one line to another, and round street corners, and through avenues at present unavailable, would be ample compensation, if made available, greatly facilitating operations, and diminishing outlay.

Supposing such tramways obtained, the next consideration is, the vehicles to run on them; for it is of no use to make curves of 35 ft. radius, and vehicles only adapted to 2 chain radius, or 132 ft. The first condition in the vehicles is, that the axles shall be capable of radiation, *i. e.*, varying from parallelism to each other to such an angle that each axle will point truly to the centre of the curve they may be traversing. This may be done, either by making the axles traverse beneath the body, or by dividing the body with a central joint, not interfering with the passageway through it; but, when this is done, it is essential also that each wheel should revolve independently on its axle, as do the wheels of ordinary omnibuses, or the vehicle will continue to be a sledge on curves. These two points being provided for, the axles may be placed at any distance apart, to guard against oscillation, and thus efficient springs become possible, with wheels of larger and more efficient diameter.

There is yet another and most important point. At present, all wheels and axles are dead weight without elasticity; the springs being above the axles and not below. What is needed is to apply the elastic principle as closely as possible to the rails. Vibration, hurtful to the health and wasteful to the mechanism, is caused by blows between the wheels and rail, but if efficient springs be interposed between the wheel and tires, the blows will disappear and the vibration also. I have for many years advocated this principle with more or less success, and with mechanical results giving conclusive evidence in its favor. Mr. Thompson, of Edinburgh, in his advocacy of india-rubber tires, has given a valuable impulse to the extension, but the object of Mr. Thompson has been their application to traction engines, as a flattening fulcrum on the road surface, to give better adhesion. Incidentally, such tires have been found to form very efficient springs, to save the machinery from damage. But there is a disadvantage in this external application. A very large mass of rubber, both in width and depth is needed; but as the adhesive pressure is only at the apex of the circle, it is essential to apply a chain and set of iron shoes to tighten it, and this involves cost and trouble. Moreover, it is necessary to use a hard quality of rubber, not so chemically durable. The true position for the rubber is between the wheel and tire, in which case the adhesive pressure extends to half the diameter of the wheel. The value of rubber can hardly be exaggerated. It is practically artificial muscle of universal action, and inside the tire it may be used in the highest condition of elasticity, and at the same time protected against all external damage. A thin tire may be used with it, which will flatten sufficiently to insure contact and adhesion in the case of driving-wheels of engines. For the running wheels of vehicles, it is desirable that the tire should maintain a true circle. We may illustrate it by the action of two blown bladders—the one partially full of air, and the other tightly distended. The former will not roll freely, the latter will. The former represents the condition desirable for the driving-wheel, the latter for the wheel of the vehicle. Such wheels will prevent all blows, both vertically on the tread, and horizontally against the rails and flanges; and when the railway authorities awaken to this fact they will find a very considerable difference in the comfort of their passengers, with an equal reduction of the cost in transit. On a rough road the difference in haulage resistance between an efficient spring vehicle and one without springs, drawn at high horse speed, is as 4 to 1 in favor of the former; and on rails, where the resistance is largely increased by lateral in addition to vertical friction, efficient springs become a matter of paramount importance. Wheels of this kind, applied to a traction engine on the common road, obtained a silver medal from the judges of the Agricultural Exhibition at Wolverhampton.

Amongst other considerations, not the least important is the possibility of speed. Other things being equal, time is equivalent to money; and to obtain great speed from horse traction, with heavy loads, is simply a question of horse killing—cruelty to animals. The average speed of the existing tramways is about 4 miles per hour, and that with serious distress to the horses. What we need is to be able to increase or diminish our speed at pleasure, according to safety. We cannot do this till we resort to the power of steam or elastic gases. Why we have not done this, is because we have not yet produced an engine combining simplicity and efficiency with tortuous transit. The engines of the railways are adapted only for straight lines, and if they run on curves it is at a great cost and waste of power, and they cannot run at all on such curves as are required for the ordinary purposes of streets and roads. Of course the steam power that can be made available must depend upon the load on the driving wheels, and that load must be governed by the capacity of the rails to carry it.

A system of rails such as described, would, without difficulty, carry a load of 2 tons per wheel. Four driving wheels could be used, making a load of 8 tons. Taking the steam power as one-fifth of the insistent load on the driving wheels, that would give a traction force of 3,500 lbs. at the rails. With the resisting friction of the vehicles reduced to the minimum by the appliances before described, the resistance per ton on the level should not exceed 8 lbs., and, theoretically, such an engine should draw a load of 450 tons on the level at 20 miles per hour, or 43 tons up a gradient of 1 in 30 at 10 miles per hour. Of course these speeds could not be used on sharp curves of very small radius, but the speed could then be reduced, and increased on the straight line. With the 2 axles of the 4 driving wheels

4 ft. apart, and a pair of trailing wheels radial, making a total wheel base of 10 ft., the tires of the driving wheels compensating on curves, such an engine would be perfectly adapted to work curves of 35 ft. radius.

One of the purposes which such a line and engine would subserve would be the connection of railways with each other. The open-channel rail would permit ordinary railway trucks to run on it, the wheels bearing on their flanges. They would, it is true, run with considerable friction, on account of the wheels being fixed on the axles, but with the tires made revolving and elastic, this would cease. But they would not work the extremely sharp curves without the axle being made to radiate. The advantage and economy of being enabled to deliver a truck-load of goods or materials from the supplier to the receiver direct, without shi ting the load into road vans, would be found so great that all needful appliances would soon follow. The engine described would be far more powerful than needed for street and surburban uses, but it would supply a want on the great public roads of no small amount.

The steam coach of Walter Hancock weighed about 4 tons, but it had 2 large driving wheels, a bad road, and varying and uncertain gradients, and, moreover, insufficient boiler power. These difficulties can now be got over. An engine with a load of less than 3 tons, on 4 driving wheels—a load far less damaging than the existing tram cars—would give a tractive force at the rails of over 1,000 lbs., equal to a load of 125 tons on the level rails, at 10 miles per hour, and could carry a supply of fuel and water for half a day; or could rise an ascent of 1 in 30 with 12 tons load, commanding all the heights round London with, say, 100 passengers, free from all risk of oscillation, and working the sharpest curves.

What, then, are the objections? Only superstition or prejudice. It is supposed that an engine must consist of a dirty-looking boiler, greasy machinery, volumes of smoke, hissing steam, and one or two very dirty men as driver and stoker. The objectors have before their mind's eye a colliery engine, or one of those used as a navvy's assistant. There is about the same resemblance between such an engine and what might be, as between a pleasure carriage and a dust cart. Both go on wheels ; but the engine may be built as elegantly as a pleasure carriage. It may have ornamental form super-imposed on its utilitarian structure. It may be painted and varnished, and adorned with utilitarian heraldry of modern times, quite as suggestive as the utility-based heraldry of the olden time—the ploughshares that won battle-fields, or the war-steeds, or cressets, or embattled towers, or iron crowns, or portcullises, or Dragons of Wantley, or Golden Fleeces, or ermined mantles, or barred helmets, or battle-axes, or swords, or scymitars. The fire-king, and the water kelpie, and the Undines, and the Northern gnomes working beneath the seated hills, and the dwarfs of the coal-mines, and Charles Wain, and all the wheels, and valves, and tools of engineering, are at the behest of the modern herald who may wish to curry favor with horses and horse-owners, by showing pleasure-engines in competition with pleasure-carriages, and remove from sight those external indications that offend the aristocratic horse, accustomed to carriage elegancies. Every piece of unpainted metal might be polished as highly as a curricle-bar, and every oil-cap closed by tight valves, and the fuel hidden away, with an ample foot-plate, and every convenience for the driver and stoker, who might thus be quite as clean and smart in externals as the driver or conductor of an omnibus, or the fastidious ruler of a Hansom cab.

"But there is the risk of explosion!" cries another objector. No doubt that risk exists in proportion to the magnitude of the boiler, but it diminishes in proportion to the decrease in size, and to the simplicity of structure. The risk increases as the square of the diameter, supposing the same thickness of metal maintained, and in small boilers the thickness of metal may be beyond all risk. We have not yet culminated to the point of perfection in boiler structure, and the processes we have to take to may be easily indicated. In boiler making, as in other things, we are apt to stick to the existing, and eschew the possible, under the nickname of theory.

But how about the smoke? Nothing very difficult. Smoke is unburned fuel, and simply waste. Coke is a very inefficient agent in producing steam. Coal, which induces lambent flame impinging on the heating surface, is far more efficient. But coal badly burned may be as inefficient as coke. Every one who pokes a smoky fire knows that the rush of air induces flame, and when locomotive engines smoke we may be quite sure that it is from want of such poking as will give air to the interior mass of heated fuel. The fire should resemble, as nearly as possible, a large lamp, with the fire impinging through the whole fire-box and tubes. In making a fire, or lighting a lamp, the first thing we have to do is to establish a gas-making apparatus. We do so when we light a rushlight, as may be seen by the small blue flame at the bottom. The best fuel, therefore, is that which is most easily convertible into gas, a process which is carried on in every oil or paraffine lamp on our tables, and, if rightly adjusted, without any smoke or smell. The best fuel, therefore, for a street locomotive would be paraffine oil, or some equivalent liquid, which passing gradually into perforated iron tubes in the fire-box, heated by a small fire of coke, would be evaporated into gas, instantly converted into flame by a sufficient supply of air. The question is only of cost, and it may be that effective fuel at a high price per ton is cheaper than low-priced, if tested by the quantity of steam produced. In using solid fuel, the essential question is, how to mix the due quantity of air with the gas as fast as it rises. To accomplish this, interstices must be provided and maintained. With gas this is easy, and the quantity may be adjusted to the demand, by turning a handle, with the greatest facility, without opening the door of the fire-box.

With regard to interstices in solid fuel, there is a manufactured fuel now about to come into the market, formed from coal dust, which, rightly applied, bids fair to supply the want by insuring the presence of air. This coal can be compressed into spheres of a convenient size, and which, when placed in the furnace, only touching each other at points, while the air rushes freely round them, the burning taking place on the surfaces, and the air passages can be maintained till the whole is consumed.

There is another source of annoyance, noise of the intermittent blast; this is now got over in some traction engines by discharging the blast into a chamber, and thence into the open air, in a continuous stream. But the true method would seem to be by splitting it into several currents. The blast of a trumpet is induced by its expanded tube form. Were the opening intersected with wires, the sound would be modulated, and a similar effect might be produced in the steam blast.

In very small engines, the chances of explosion may be reduced to the bounds of a very small possibility, but that possibility may be reduced to an impossibility by varying the medium through which the heat power is used, substituting air for water. In the use of steam, a magazine or accumulator is needed, containing a large supply under pressure. In the use of air, the pressure required is obtained at every stroke of the piston, without any accumulation. Steam is used at a pressure of 100 lbs. to the inch. Hot air does not exceed 15 lbs. to the inch. Therefore, to obtain a given power, a much larger cylinder is required in the case of hot air than is required with steam, and the weight of the machine is increased; but to set against this, the hot air requires no boiler. The blast of air driven through the fire intensifies the combustion, and swells its volume to the required pressure. The sound of the blast in escape is of course subject to the same conditions as the steam engine, and can be dealt with after the same methods. There would be no difficulty in constructing a hot air locomotive, weighing not more than 3 tons, to develop a traction force of 600 lbs. at the rails—a force ample for the purpose of drawing a load of 600 passengers through the streets and suburbs of London.

Such an engine could no doubt be made to do its haulage equally well on asphalt as on rails, with the exception that it would cease to be self-guided, and must be provided with arrangements accordingly.

The outlay for such an engine would probably not exceed that required for the purchase of a stud of horses required for working an omnibus of equivalent load, with the advantage that the engine would work incessantly without falling sick, and that the cost of working it would be scarcely one-eighth that of the horses, and it would not be subject to dying. It would carry with it its fuel for a whole day, eating its carbon while working, instead of knocking off like horses to their oats or maize; and the rises and falls in the price of fuel would be less than those of the horse food. Moreover, the engine would not destroy the road with 8 pickaxes, like the 8 horse-shoes, and the gases discharged by the blast without smoke would leave no residuum like that marking the track of the horses with a common nuisance. The source of dispute between tramway and omnibus horse owners would cease, inasmuch as horse owners could not live under the competition of steam, or hot air.

The better housing of the working classes, now imperatively urged as a necessary means of national progress, can only be accomplished in its most desirable condition by the aid of cheap transit, and it has been proved that the largest source of profit to transit companies is "third-class," in other words, the great masses of working humanity. The humanizing influence of gardens may be accessible to some of the families of working men as distance vanishes in mechanical facilities. If commercial stimulus induces a company to work in this direction, it will be a great advance on the morals, prosperity, and happiness of our great commercial and manufacturing cities; but till we can get mechanical power substituted for horseflesh as the means of transit, we shall be as far behind in the results as are omnibuses and stage coaches compared with railways—at a given cost doing only one-eighth of the work.

SEWAGE AS A FERTILIZER OF LAND, AND LAND AS A PURIFIER OF SEWAGE.*

From "Journal of The Society of Arts."

Though large figures have been put forth, by sundry writers and speakers, of the immense loss this country suffers by casting the sewage of its towns into the rivers, and everybody acknowledges, not only that such waste ought not to continue, but that our rivers should be restored to their original purity, we have not yet brought to practical test the value of sewage to the farmer and the market gardener. Chemists have done their best to rouse public attention to the loss we suffer, and it now remains with the country to adopt those measures which will best conduce to its recovery.

Large as the intrinsic value of the fertilizing matter has been shown to be by the chemist, the value of the water in which it is contained has been excluded from his consideration, though farmers and gardeners alike are prepared, after the experience of the recent years of drought, to put a high value on water for its own sake, irrespective of the fertilizing elements it contains after sewage has been mixed with it, for they know how serviceable is timely moisture to the germination of seed, and for reviving and sustaining plant growth, independently of its special power of conducting to the roots of plants, in the most acceptable way, those fertilizing ingredients which the chemist has valued so highly.

Hitherto, the benefit to be gained by a command of water has been more than counterbalanced by the disadvantages of excess, and the obligation of disposing of the liquid sewage at all times and under all conditions. In referring to water, therefore, I do so only to remark that, large as the theoretical value of the manurial properties of sewage has been declared to be, it may yet bear an increase when the practical mind of the agriculturist is brought to bear on its utilization, and the disadvantages under which a new branch of industry always suffers are overcome.

A HIGH STANDARD OF PURITY OF WATER ESSENTIAL.

But so slow and so naturally sceptical, in respect of new appliances, is the agricultural mind, that we must not wait for the recognition of the cultivator as the only thing necessary for the development of the value of sewage. We must rather trust to the obligation which will before long be imposed on all sewer authorities, so to treat the liquid refuse of towns that the effluent liquid shall conform to a recognized standard of purity; for it will only be by the most stringent enforcement of

* A paper read before the Society of Arts by J. Bailey Denton, C.E., F G S., Member of the Royal Agricultural Societies of Norway, Sweden, and Hanover.

the law in this respect that all the manurial properties of sewage will be rendered available for reproduction.

Taking this view, I think it is much to be regretted that the Conservators of the Thames have, without pledging themselves to any positive decision, recognized a standard of purity in some degree inferior to that suggested by the present Rivers Pollution Commissioners in their first report, and that they have done so in the face of a statement by the Commissioners, that they made the suggestion with the "belief that, as science progresses, improved methods of purifying polluted liquids will be discovered, and that eventually standards of purity considerably higher than those recorded may, if necessary, be enforced." Without presuming to give any opinion upon the details of the standard suggested by the Commissioners, which I know is regarded by some chemists as objectionable, I am content to record the fact that their anticipation has already been in a measure realized. This is not mere assertion; it has been conclusively shown that when natural soil is so prepared, by properly designed deep drainage and deep surface cultivation, that the whole of the sewage distributed upon its surface is absorbed and percolates *evenly* through the soil, the effluent liquid passes into the arterial outfalls from the under-drains purified to a very high degree, and unobjectionable in every respect. Such, in point of fact, appears to be the purification effected by oxidation, resulting from the aëration of drainage and the intermittent use of soil for filtration, that it is not at all a too sanguine view to take, that, with increased experience, we may arrive at a power of restoring water with which sewage has been mixed to its original potable condition.

For the convenience of those interested in the matter, I here give the standard suggested by the Rivers Pollution Commissioners, and will add that which has been circulated by the Thames Conservators. The Commissioners suggest that the following liquids be deemed polluting, and inadmissible into any stream:

(*a.*) Any liquid containing in suspension more than 3 parts by weight of dry mineral matter, or 1 part by weight of dry organic matter in 100,000 parts by weight of the liquid.

(*b.*) Any liquid containing in solution more than 2 parts by weight of organic carbon, or .3 parts by weight of organic nitrogen in 100,000 parts by weight.

(*c.*) Any liquid which shall exhibit by daylight a distinct color when a stratum of it one inch deep is placed in a white porcelain or earthenware vessel.

(*d.*) Any liquid which contains in solution, in 100,000 parts by weight, more than 2 parts by weight of any metal except calcium, magnesium, potassium, and sodium.

(*e.*) Any liquid which, in 100,000 parts by weight, contains, whether in solution or suspension, in chemical combination or otherwise, more than .05 part by weight of metallic arsenic.

(*f.*) Any liquid which, after acidification with sulphuric acid, contains, in 100,000 parts by weight, more than 1 part by weight of free chlorine.

(*g.*) Any liquid which contains, in 100,000 parts by weight, more than 1 part by weight of sulphur, in the condition either of sulphuretted hydrogen or of a soluble sulphuret.

(*h.*) Any liquid possessing an acidity greater than that which is produced by adding 2 parts by weight of real muriatic acid to 1,000 parts by weight of distilled water.

(*i.*) Any liquid possessing an alkalinity greater than that produced by adding one part by weight of dry caustic soda to 1,000 parts by weight of distilled water.

The following standard of purity for defecated water is that recommended by the chemists consulted by the Thames Conservators, and it will be seen that it is, as I have stated, less stringent than that suggested by the Rivers Pollution Commissioners. They say: "1. It should be free from an offensive odor. 2. It should be free from suspended matters, or, in other words, be perfectly clear. 3. It should not be alkaline to turmeric-paper, nor acid to litmus-paper. 4. It should not contain per gallon more than 60 grains of solid matter dried at 260 deg. Fahr. 5. It should not contain more than $\frac{3}{4}$ of a grain of organic and ammoniacal nitrogen per gallon. 6. It should not contain more than 2 grains of organic carbon per gallon. 7. It should contain not less than 1 cubic inch of free oxygen in a gallon." It should be observed, however, that one of the eminent chemists who signed this recommended standard, Dr. Frankland, being himself a member of the Rivers Pollution Commission, added these words: "The conditions under which fluid which has been contaminated with sewage may be admitted into the Thames, as prescribed in the foregoing report, will, I have every reason to believe, preserve the river from being offensive to the inhabitants upon its banks; but, whilst thus far agreeing with my colleagues, I wish it to be distinctly understood that, in my opinion, such fluid can only be safely admissible into the Thames on condition that the water is not afterwards used for domestic purposes."

The conservators of the river Lee, in the absence of any standard recognized by the Government, have hitherto abstained from issuing one of their own, and the consumers of water in the metropolis are to be congratulated that they have done so; for the publication, limited though it has been, of the lower standard recommended to the Thames Conservators, has already had the effect of encouraging results inferior to those which are to be desired. The Lee Board reserves to itself judgment until the towns discharging into the river have completed their purifying works, for which they have extended the time, at the expiration of which it is to be hoped that some positive action towards the establishment of standards to fit different circumstances will have been taken by the central local government authority. Until such is the case, we shall probably see, both on the Thames and on the Lee, the sewer authorities of towns disregarding, naturally enough, the higher standard of the Rivers Pollution Commissioners, and in spite of the protest of Dr. Frankland, and the general sense of the country, the inhabitants of London may be compelled to drink polluted water, and, as a natural consequence, the contamination of our streams will continue throughout the length and breadth of the land.

This point, however, is not that upon which I desire to dwell. It is of sewage as a fertilizer of land that I must speak, though it is right to repeat emphatically, what must be manifest to every practical mind, that so long as the pollution of rivers is permitted in a modified degree by the recognition of any standard of inferior character, the fertilizing ingredients of sewage will not be wholly recovered from the water with which they are mixed.

SEWAGE AS A FERTILIZER OF LAND.

To show what is the intrinsic value of the fertilizing ingredients of sewage, I will in the shortest manner possible, state the conclusion to which Messrs. Lawes & Gilbert came in 1866, in their very complete and careful paper on the "Composition, Value, and Utilization of Town Sewage," read before the Chemical Society, and which, I believe, expresses pretty accurately views in which the majority of those who are competent to deal with the subject concur. Having adopted the case of Rugby as a fair sample of water-closet towns, the discharged sewage being equal to 36 gallons per diem, or 60 tons per head per annum, including surface and subsoil waters, they stated that, "looking to the average results of 93 analyses," they found "that the sewage contained about $87\frac{1}{2}$ grains per gallon of total solid matter, of which about $\frac{2}{3}$ was inorganic and $\frac{1}{3}$ organic. About half the total solid matter was in suspension, and half in solution; of the half in suspension about $\frac{4}{7}$ was inorganic, and $\frac{3}{7}$ organic, and of the half in solution about $\frac{4}{5}$ was inorganic, and $\frac{1}{5}$ organic. Lastly, of the nitrogen, reckoned as ammonia, about $\frac{1}{4}$ was in suspension, and $\frac{3}{4}$ in solution. The mean of the 93 analyses showed about $6\frac{1}{2}$ grains of ammonia per gallon, indicating a value of $1\frac{2}{3}$d. for the total constituents in 1 ton of sewage." These figures, multiplied by the 60 tons of sewage per head per annum, resulted in showing "that $12\frac{1}{2}$ lbs. of ammonia were contributed annually for each average individual of the mixed population of both sexes and all ages." This quantity of ammonia, at 8d. per lb., gives 8s. 4d., or 100 pence, as the value of sewage per head from water-closet towns. Various other estimates have been made of the sewage of water-closet towns. Dr. Letheby took samples, at noon and at midnight, from a number of sewers in the metropolis, and arrived at the conclusion that 7.24 grains represented the mean quantity of ammonia per gallon. Messrs. Hofmann and Witt, having treated one particular sewer, considered that 8.21 grains represented the quantity of ammonia. These two quantities would, if taken at the same price of ammonia, result in larger figures than those of Messrs. Lawes and Gilbert.

There have been several estimates made of the value of sewage, by modes of computation differing from that based on the whole sewage of towns as discharged by the sewers, and as they will assist us in considering what proportion of the excrementitious matter of the closet may be kept out of the sewers, with benefit to agriculture and profit to the ratepayers of sewered districts, I will shortly refer to them. Messrs. Hofmann and Witt, and Dr. Thudichum, having ascertained the amount of urine and fæces voided by individual persons, taking an average of both sexes of all ages, valued the urine at 7s. 3d. and the fecal matter at 1s. $2\frac{3}{4}$d., which together, it will be observed, is very nearly the same amount as that put upon the whole sewage by Messrs. Lawes and Gilbert.

There is an anomaly in these estimates which has to be reconciled, inasmuch as it appears that the excrements of human beings alone, exclusive of the refuse from slaughter - houses, stables, cow-houses, and dog kennels, as well as that discharged from the kitchen, with its refuse of vegetable and animal food, is more valuable than the whole liquid refuse of a town, when the contents of the closet are discharged into the sewers as well as all other refuse. And the anomaly becomes more difficult of reconciliation when we have to consider a statement by the Rivers Pollution Commissioners to the effect that, comparing water-closet towns in which the whole of the sewage issues from the sewers, with "midden" towns, in which a considerable portion of the human excreta is detained and disposed of separately, there is a remarkable similarity of composition between the two.

I will not detain you by any endeavor to reconcile these analyses and statements, but will only remark that, assuming them to be correct, an important consequence follows, viz., that, in an agricultural view, it is desirable to treat the excremental contents of privies separately, for if no appreciable loss of fertilizing matter is found to exist in liquid sewage when separated from that of the privies, it is manifest that a decided national gain is obtained by the maintenance of the two systems, inasmuch as the dry, portable manure obtained from the privy contents will be so much fertilizing matter available for distant lands, in addition to the liquid sewage, which may be utilized by irrigation near at home.

But the realization of the fertilizing value of sewage in the liquid state depends necessarily upon two preceding conditions, the first being the obligation which should be imposed on all towns by the central local government authority, to *perfectly* cleanse their sewage ; and the next, the preparation by the sewer authorities of the land designed to receive the sewage, in such a way that the whole may be *fully* utilized. With these two duties performed, and not otherwise, there is a fair prospect of at least a penny a ton being realized for liquid sewage of average strength, half of which (as I have stated on former occasions) should go into the pockets of the ratepayers, in repayment for the necessary works, while the other half will be due to the cultivator as a return for his industry and the employment of his capital.

Excluding from consideration the value of the water, which, I contend, will become a great item in the profitable treatment of sewage, the subject before us may be classified under three heads, viz.—(1.) Where the whole of the sewage is treated by chemical process at the mouth of the sewer. (2.) Where it is transported from the sewer mouth to land for distribution there. And (3.) Where a part of the excrementitious refuse is treated separately from the remainder. The question which addresses itself, therefore, to the authorities of all sewered districts is, which of these methods of treatment will best enable them to effect the twofold object of purifying the sewage and utilizing it to the greatest advantage ?—while the question which the agriculturist has to consider is, which method will place at his command at a fair price and in the most productive shape, the fertilizing matter which the sewer authorities must extract, in order to cleanse the sewage perfectly ?

I.—*Chemical treatment of the whole of the Sewage at the mouth of the Sewer.*

Leaving out of consideration all treatments which aim only at the purification of the sewage, without turning its fertilizing properties to use, as irrelevant to my subject, I will confine my observations to those chemical processes by which both these objects are said to be obtained. Many processes have been before the public aiming at this end, and several have been patented, and afterwards brought forward by public companies. The Native Guano Company, better known as the company possessing the patent of the "A B C Sewage Process," now stands very prominently before the public in consequence of its shares being at a high premium, and because arrangements have been made by the authorities of Hastings, Leeds, Bolton, and Southampton, as well as by the Metropolitan Board of Works, to test by comprehensive experiments, the value of the process, although it had been superseded at Leamington by irrigation. The initials "A B C" indicate the principal ingredients of the chemical mixture, viz., alum, blood, and clay, by which it is stated the polluting and fertilizing parts of sewage may be precipitated and made available as a manure. I do not propose to enter into any details of the process itself, but will merely state that the specification of the patent sets forth that 4 lbs. of mixture are required for every 1,000 gallons of sewage treated; and that Mr. Rawson, the general manager of the company, tells me that 100,000 gallons of sewage of average strength—diluted to the extent of 30 gallons a day—will produce from 20 to 25 cwt. of dry manure; from which statement we see that, if the specified proportion of mixture to sewage were adhered to, 400 lbs. of mixture will be required for the production of a ton of salable manure. The company declare that deodorization takes place immediately on the first addition of the A B C mixture, and in proof of the purification effected, give the following analyses:

Comparative Analysis in Grains per Gallon.

	Average of 50 samples Sewage.	Average of 50 samples Effluent Liquid.
Organic matter	17.2	1.4
Mineral matter	37.4	16.9
Total	54.6	18.3

I will now offer such evidence as I can of what the Native Guano Company can do towards the purification of sewage and the extraction of its fertilizing parts, premising that Mr. Rawson has most courteously afforded me every facility for ascertaining the results arrived at by farmers and gardeners who have used the manure sold by the Company.

The Rivers Pollution Commissioners, having made very careful experiments at Leicester and at Leamington, state in their second report (dated 4th July, 1870), that the process removes a very small proportion of the soluble polluting matter from sewage, and that "the manure obtained has a very low market value, and cannot repay the cost of manufacture." Their analysis of the effluent liquid, made of samples taken on the 10th of May, 1870, showed the following result, although the quantity of mixture used was increased very largely beyond the proportion prescribed in the specification (4 lbs. to 1,000 gallons of sewage).

Analysis expressed in parts per 100,000:

Total solid matter in solution	123.05
Organic carbon	4.727
Organic nitrogen	1.892
Ammonia	8.060

These figures are very much in excess of those I have just quoted as given by the Company; though, if the latter were compared with either the standard of purity suggested by the Rivers Pollution Commissioners or that recommended to the Thames Conservators, it will be seen that the condition indicated is not such as to render the effluent liquid admissible into running streams. How Leeds and the other towns mentioned will ultimately conform to a national standard of purity remains to be seen. As to the manure made by the native Guano Company, the Commissioners said that "the so-called A B C manure is little more than the original suspended solid matter of raw sewage plus the insoluble materials added in the A B C mixture, $\frac{19}{20}$ of this being merely clay."

The chemists employed by the Metropolitan Board of Works state, through Dr. Odling (June 24, 1870), when speaking of this process, that, after examination, they found "there was a great deal of putrescible matter in the effluent liquid; and in comparing this mode of precipitation with others, it did not seem that its alleged superiority had any foundation."

Dr. Voelcker, in the "Journal of the Royal Agricultural Society" vol. vi., S. S, Part ii.), having analyzed five different samples of the manure sold as native guano, stated the result to be as follows:

	£	s.	d.	
No. 1 sample was worth	0	18	6	per ton.
2 " "	1	13	6	"
3 " "	0	14	0	"
4 " "	0	18	6	"
5 " "	0	14	6	"

basing his value on a comparison of the manure with phosphate of lime, at £10 a ton, and ammonia at £60 a ton.

Still, in the face of these adverse opinions, expressed by the highest chemical authorities of the country, the Native Guano Company is advertising its dried manure at £3 10s. per ton, and are finding customers at that price. Some farmers and gardeners with whom I have corresponded speak very favorably of it, and declare their intention of buying more, while others say they have not been able to distinguish any advantage from the use of it, and one farmer goes so far as to threaten an action for injury done by its use.

On the whole, the replies I have received do not lead me to the conclusion that the sale of the manure will be very great after public curiosity is satisfied, for it is more than probable that the sales that have taken place have resulted from the desire to give the manure a trial, under a false notion that because Peruvian guano is advertised at £13 5s. a ton, and phospho-guano at £11 10s. a ton, "native guano" must be cheap at £3 10s. a ton. If, however, the sale should continue, the failure of the process to effect purification up to any recognized standard must act as a veto to its adoption, except in those cases where the authorities of towns may be content with clarified in the place of purified sewage.

The Phosphate Sewage Company, founded on a patent taken out by Dr. David Forbes, of which dissolved phosphate of alumina for precipitation is the base, aims at doing all that the A B C process professes to do, with the additional recommendation of being associated with irrigation where circumstances favor the adoption of the two processes, which, seeing that the separation of the coarser solid parts of sewage from the liquid is a desideratum in irrigation, may frequently be the case. The Company state that "if phosphate of alumina alone is used, the sewage is defecated, the solid matter is precipitated, and the water is left still maintaining all its nitrogenous and valuable properties, plus any excess of phosphoric acid which has been added, and, therefore, highly useful for the irrigation of cereals and other crops, and at the same time perfectly inoffensive. This process will be adopted where it is deemed desirable to use the water as a fertilizing agent for irrigation purposes, since it posse ses advantages, both in an agricultural and sanitary point of view, above any system of sewage irrigation hitherto used.

In the case of towns to which sewage irrigation is inapplicable or disadvantageous, and which are desirous of rendering their sewage water sufficiently clear and pure to return into a river or stream, this object can be effected by adding a small quantity of lime to the sewage after treatment by the former process." This Company, in fact, declares itself able not only to purify sewage to a degree to render it admissible into rivers, and to manufacture a manure out of the precipitated matter, but to render the effluent liquid more suitable for irrigation than the sewage itself. These statements are made on the authority of Dr. Voelcker. The analysis of the effluent liquid discharged during certain trials at Tottenham gives the following result in grains per imperial gallon :—

Organic matter—		
In solution	5.74	
In suspension	none.	
Total organic matter		5.74
Mineral matter—		
In solution	57.71	
In suspension	none.	
		57.71
Total solid matter (organic and mineral)		63.45
Organic nitrogen—		
In solution	.47	
In suspension	none.	
Total organic nitrogen		.47
Equal to ammonia	.57	
Saline ammonia	332	
Total nitrogen calculated as ammonia.	3.89	

Compared with the suggested standard of the Rivers Pollution Commissioners, this analysis does not show the requisite amount of purity.

I have endeavored, from information supplied me by Mr. Lonsdale, the secretary of the Company, to obtain some tangible proofs of the value of the manure manufactured by the Company, but the number of instances are so few in which actual trial has been made on a scale affording any practical test, that I confess myself unable to draw any deductions whatever ; and when stating there can be no doubt that a valuable manure may be made by mixing with the fertilizing parts of sewage the phosphate of alumina, it must be borne in mind that there exists no proof that the manufacture will be attended with profit. It must also be remembered that the operations of the Company depend upon the supply of phosphate of alumina, which, like all other foreign importations obtained from a distance, must be liable to vicissitudes bearing upon the fortunes of the Company, and on the interests of those towns and districts having dealings with it. Associated with irrigation as a never-failing resource when the phosphate may not be forthcoming or when the manure may not command a sale, such objections would not exist.

With certain seaboard towns, where the effluent sewage need only be clarified to be free from objection, this Company, like the Native Guano Company, may probably do a large amount of work, if it should turn out that a salable manure may be profitably made; though, with the experience we are now having of the power of a small quantity of natural soil to cleanse a large body of sewage by intermittent filtration, and to grow crops at the same time, so that the scavenging powers of vegetation may render their aid in purification (as I shall presently show may be the case), it will probably be found more economical to have recourse to that process which is attended with no nuisance whatever, than to establish manure manufactories with all the attendant risks.

Not having any information to offer with regard to the Peat and Engineering Company, nor of any other chemical or chemico-mechanical processes which deal with the sewage at the sewer mouth, I have nothing further to add about that class of treatment. I will merely repeat that it is daily becoming more generally acknowledged, and acted upon, that "the present resources of chemistry appear to hold out no hope that the foul matters dissolved in sewage will be precipitated and got rid of by the application of chemicals to the offensive liquid," and that therefore we must look to the direct application of sewage to land wherever it can be obtained for the purpose, as the most desirable means of recovering from water those "ingredients held by it in solution and suspension which do not belong to it, and which render it objectionable and unfit for ordinary and domestic purposes."

II. Transport of the whole Sewage in its liquid state from the Sewer Mouth direct to the Land, for distribution on the Surface.

So much has been written and said recently on the practice of sewage irrigation, that I should be disposed to say very little on the subject, had not the special properties of the soil itself for appropriating the fertilizing matter of sewage, and for cleansing the sewage itself, been, to a very great extent, omitted from consideration and had not Boards of Health—the worst farmers in the world—been the principal cultivators up to the present time. Believing that, with a recognition that the soil will perform the functions accredited to vegetation as or more effectually than vegetation itself, and that the two in combination will obtain the best results, both as a means of profit and as a sanitary agency, I regard all calculations that have hitherto been made as to the number of persons contributing sewage per acre, and the rules that have been laid down on that score, as worth very little as a guide for the future, when the principle shall be fully recognized that the surface of land must be rendered so absorbent that no sewage shall pass off into the river courses.

In the application of sewage to land, the local features will, in future, decide the question whether the purification of the sewage and its profitable use should be treated as objects of equal importance, or whether the purification should be the paramount object, and utilization a subsidiary one. If sufficient land for wide irrigation is not to be obtained, or if obtained only at a price that shall place the application of the sewage, by way of irrigation, beyond the possibility of profit, it is manifest that we must call to our aid the cleansing powers of an aerated soil, and regard the land more in the character of a filter than we have hitherto been disposed to do; and by adopting intermittent application, the effect of which has been so admirably explained by the Rivers Pollution Commissioners, realize all the advantages to be gained from it.

The two processes of irrigation and filtration are already viewed so differently from the way in which they were regarded in their first introduction, that it is necessary to state how we stand with regard to them at the present moment. It will be remembered that, up to very recently, an opinion prevailed with respect to irrigation that, "the object of getting sewage on to the land was, not to let it percolate into the ground, but to keep it on the surface," and that subsoil drainage would not do for sewage farms, because the sewage passed too rapidly to the roots of vegetation, and descended downwards.

Under-drainage as Essential to Irrigation as to Filtration.—Some members of this Society may remember, on the occasion of my reading a paper on "The Water Supply of the Metropolis, in Relation to the Thames and its Tributaries," my friend Mr. Rawlinson, who has ever been the consistent and able advocate of the application of sewage to land, stated in this room, without giving any opinion himself, that some persons practically "acquainted with sewage irrigation would prefer, from their experience, to irrigate clay lands without under-drainage, if Italian ryegrass, which was the most profitable crop, were to be sown;" and the little difference of effect that was to be noticed at Norwood, where the land was clay, and the manager had actually plugged the drains in order to keep the land in a state of supersaturation, when compared with Croydon, where the land is free, and is naturally drained, has often been quoted as a reason why sewage-irrigated land should not be drained. I will not stop to condemn this view, which is repugnant alike to the sanitarian and the agriculturist, as it may be already observed that, with very few exceptions, indeed, operators now disclaim the opinion that under-drainage is unnecessary. So decided has the appreciation of drainage become with the majority of sewage irrigators, that in the eagarness to secure rapid absorption, sewage farms have become filter beds of too rapid action, and by the adoption of inappropriate drains the purifying powers of the soil have been jeopardized. Short as the interval has been since the intermittent downward filtration was first suggested by the Rivers Pollution Commissioners, that process has, like irrigation, undergone a change. The Rivers Pollution Commissioners stated—evidently under the impression that sewage would only be applied to a barren or fallow surface—"That with a properly constituted soil, well and deeply drained, nothing more would be necessary than to level the surface and divide it into 4 equal plots, each of which in succession would then receive the sewage for 6 hours. In this way the sewage of a water-closet town of 10,000 inhabitants could, at a very moderate estimate, be cleansed upon 5 acres of land, if the latter were well drained to a depth of 6 ft." They then go on to state that, nevertheless, there are three formidable objections to the general adoption of the process :—(1) "It is entirely unremunerative." (2) "The whole of the manurial ingredients of the sewage would be absolutely wasted." And (3) "The collection of solid fecal matters upon the surface of the soil, with no vegetation to make use of them, would probably give rise to a formidable nuisance, especially in hot weather." The change to which I have referred has arisen on the proof which I have had the satisfaction myself of affording, that vegetation may be grown upon the surface of filtering areas, even when receiving sewage equal to the discharged refuse of 3,000 persons to each acre, thus adding, in the most apposite manner, to the cleansing powers of the soil the scavengering properties of vegetaiton. When speaking presently of land as a purifier of sewage, I shall give the particulars of the instance referred to, which, though the first and only case in which intermittent filtration has been tried and modified by the growth of crops, cannot fail to prove that the objections anticipated by the Rivers Pollution Commissioners may be avoided.

Technical Description of Irrigation and Filtration.—With the general admission that under-drainage is essential wherever sewage is applied to the surface of land, it must now be generally understood that irrigation means the distribution of sewage over as many acres as it will wet without supersaturation, having in view a maximum growth of vegetation from the amount of sewage applied, and that any departure from this, resulting in excessive application, is a waste of fertilizing matter. I think it may also be taken as proved that filtration through soil should not necessarily mean its application to a fallow or barren surface (as contemplated by the Commissioners), but the concentration of the sewage, intermittently, on as few acres of land as will absorb and cleanse it, without excluding the production of vegetation at the same time.

Irrigation.—Having given the interpretation of irrigation as the application of sewage to as many acres as it will wet without supersaturation, I should point out that, owing to the absence of a proper apportionment of the sewage at command to a certain quantity of land, considerable waste has resulted in most instances of sewage farming. The Italian irrigators reckon that they lose half their water when carrying the other half forward for use ; and having the advantage of enormous quantities of water to deal with, and a power of regaining that which was absorbed by the soil, by tapping it at a lower level, they are indifferent to loss ; but in England, where we reckon the value of sewage by the ton, and have taken its intrinsic value at 1d. per ton, we cannot be content to follow such an example. We must, in fact, in this country reject any mode of distributing sewage which does not aim at the utmost economy, and which I may here state would not be attained, in my opinion, if the average quantity of sewage applied to each acre per annum exceeded 2,000 tons, which represents the sewage (proper) of 62 persons, with a water supply of 20 gallons a head.

Land may be too Porous.—To judge of the waste resulting from the present mode of applying sewage to the surface of land, we have only to look to the reports of the proceedings at the Lodge Farm, near Barking, published by Mr. Morgan, to whom the public are greatly indebted for the explicit way in which he has given the quantity of sewage applied and of vegetation grown, and we shall see that an average quantity of 4,435 tons of sewage per acre were applied during the year ending the 31st of August, 1870, while the quantity used up to the 31st of August last was 3,808 tons per acre. If we put ½d. a ton—which I have said sewer authorities ought to receive for their sewage—on each of these quantities, we find that the payment in the first year would have been £9 4s. 9d., and in the last £7 18s. 8d. Turning again to Mr. Morgan's report, it will be seen that as much as 21,488 tons of sewage have been applied per acre in one field of Italian rye grass. This at ½d. a ton would amount to £44 15s. 4d. This is the extreme of the year, but taking the whole of the Italian rye grass produced, it will be seen that the average quantity of sewage applied from the date of sowing was 288 tons for every ton of rye grass produced and cut. At ½d. a ton the tenant would have to pay 12s. for this, which is the value of the grass when cut ; so that he would suffer a loss of all outgoings in the shape of rent, rates, labor, seed, etc. The waste exhibited by these figures is clearly due to the extreme porosity of the soil, and its unfitness for irrigation on that account.

A Proportion of Clay Desirable.—With the limited time at command I must not enlarge upon the advantages certain soils have over others for irrigation. It may be sufficient to state that, if we desire to make the most of sewage, it is necessary that a proportion of clay should exist in the soil, and that, although very stiff clays, from the difficulty attending their management, should be avoided, it is much more likely that soils may be too free than too stiff ; I am now, of course, speaking of the retention of the fertilizing matter of sewage by the soil, and not of the process of filtration as a means of purification. That is quite another matter. That clayey land is more grateful for sewage is very distinctly shown by Mr. Morgan's report, for the same quantity of Italian rye grass was produced from clay lands as from free soils, though Mr. Morgan informs me the former did not absorb more than 4,000 tons per acre, which is a little more than ⅓ of the sewage applied to the Italian rye grass grown on the free soils. I need hardly point out that the rapidity with which land will absorb sewage must depend, not only upon the nature of the soil—its density and porosity—but equally upon the inclination of the surface over which the sewage travels, and the character of under-drainage beneath, and that, therefore, it is the duty of the engineer, when laying out land for absorption, to regulate the inclination of the surface, and the number, position, and size of the under drains *upon which the effect mainly depends*, according to the degree of porosity of the soil, in order that a given quantity of sewage may go as far as possible.

Filtration.—Having dwelt upon the practice of irrigation, I ought now to explain the process of intermittent filtration as it may be carried into practice, but as I shall presently deal with it when considering "land as a purifier of sewage," I will only state that by adopting the process as technically described, the liquid refuse of from 1,000 to 3,000 persons—and probably more—may be cleansed by the soil of a single acre of land.

Return from Irrigation.—Up to this time, though sewage-farming has been practised for some years, we have not obtained sufficient data for the guidance of those who desire to follow it as a business. Although local boards and companies have had the farms in their own hands, no balance-sheets, showing the quantity of sewage applied to, and the money realized by the sale of, the various crops grown, have been published. Still, the occasional results that have been obtained afford us positive evldence of what will be done under the management of men practised in the cultivation of land.

The following table exhibits certain results obtained at various places at different dates :—

Description of Crop.	Years of Production.	PLACE.	Value of Crop Per Acre.		
			£	s.	d.
Italian rye grass	1868	Norwood	22	0	0
	1869	Lodge Farm, Barking	25	0	0
	"	Norwood	25	0	0
	"	Edinburgh	32	0	0
	1870	Lodge Farm, Barking	37	0	0
	1871	" "	22	0	0
	"	Warwick	12	14	0
	"	Banbury	13	16	10
Mangolds	1870	Lodge Farm, Barking	32	0	0
	1871	" "	44	0	0
	"	Warwick	26	5	0
	"	Rugby	21	9	0
Swedes	1871	Warwick	26	5	0
	"	Rugby	18	15	0
	"	Banbury	14	6	8
Carrots	1869	Lodge Farm, Barking	38	0	0
	1870	" "	45	0	0
	1871	Rugby	45	0	0
	"	Warwick	35	0	0
Parsnips	1868	Lodge Farm, Barking	35	0	0
	1870	" "	35	0	0
	1871	" "	52	0	0
	"	Warwick	35	0	0
Cabbages	1868	Lodge Farm, Barking	35	0	0
	1870	" "	15	0	0
	1871	" "	24	0	0
	"	Banbury	21	11	6
	"	Warwick	35	0	0
	"	Rugby	15	0	0
	"	Merthyr	20	0	0
Potatoes	1869	Lodge Farm, Barking	33	0	0
	1870	" "	25	0	0
	1871	" "	18	0	0
Onions	1869	" "	38	0	0
	1870	" "	62	0	0
	1871	" "	104	0	0
	"	Warwick	35	0	0

From these instances sufficient proof is afforded that, with one crop per annum of a kind that will yield largely to the application of sewage, and command a certain and ready sale in the neighborhood, a sufficient return may be gained to pay a full rent for the land and a halfpenny a ton for the sewage, besides affording a good profit after paying all out-goings in the shape of rates, taxes, hand and horse labor, repairs and restoration of implements, seeds, interest on capital, etc. It is true that crops as large and even larger than those grown with sewage have been produced by good farming without sewage, and there would be nothing to say specially in favor of irrigation, were it not that the *united* advantages of manure and water insure crops year after year under every vicissitude of season, and allow of two crops being taken from the same land occasionally. From the experience gained in the cultivation of Italian ryegrass, it is found that it may readily be grown in excess of the demand for it in a green state, and that, as this description of grass is most difficult to convert into hay, it is desirable to limit its growth to a narrower space. It absorbs and appropriates, however, a larger proportion of sewage than any other description of crop, and it is only because it thus helps to swallow up sewage that it is continued to be grown by those who seek rather to get rid of the sewage than to make the most of it. That specialty loses its force directly a fair value is put on the sewage, or when sewage is applied to land which is itself capable of absorbing and cleansing it, as in such case the manurial matter is stored in the soil for use by following crops.

Return from Intermittent Filtration.—The acreage return to the cultivator from the growth of crops on land used for intermittent filtration will depend upon the extent to which the intermittent principle is extended. If several series of filtering beds are adopted, as I have advised in the case of several towns, among which I may mention Birmingham, where the Sewage Inquiry Committee have declared their intention to adopt it, the return will be found to be quite as great if not greater than that to be obtained from irrigation; for with the land rendered actively absorbent by drainage and deep cultivation, and laid up in bouts or ridges, crops may be grown while the sewage is being applied, without suffering from excess of wetness. By extending the filtering process from one series, as suggested by the Rivers Pollution Commissioners, to several series of areas, so as to give two or three years' rest from filtration, such lands become available for the growth of the greatest amount of vegetation that can be produced from the land; for with the sewage at command, any amount of watering that the crops require can be obtained by diverting the sewage for a time from the filtering areas in use. At Merthyr, the money realized by the sale of crops, comprising various roots and cabbages, grown between the 14th June and 31st August last, amounted, on an average of a day's sale by auction, to £17 15s. per acre, while the crops which were sold afterwards realized upwards of £20 an acre. These figures will bear comparison with the returns from irrigation proper; and I may here state that although the works have been very costly, owing in a great measure to their being the first of the kind carried into execution, and in being themselves the result of Chancery proceedings, the Chairman of the Board (Mr. William Jones, of Cyfarthfa), says in a letter to me that much as the land and works have cost, "the filtering areas may yet pay;" adding that "had we obtained the land at a fair agricultural value, and the works been executed at the cost they would now be executed for, with acquired experience, I have no hesitation in saying that they would be a source of great profit to the ratepayers of this district." These figures and the chairman's opinion are encouraging, and show a fair prospect of profit, if the authorities who have charge of such works abstain from growing the more refined kinds of gardeners' crops, which involve expensive hand-labor, and which are dependent on very fickle markets for sale.

Many considerations lead to the conviction that it will seldom be within the power of the sewer authorities of towns to adopt the widest use of sewage, which would result in the provision of one acre for rather more than 40 persons, if we adopt the rate I have before stated, of 62 persons to one acre, with an allowance of 50 per cent. additional land for increasing population. With constantly arising opposition based on a fear of a nuisance (which under proper management will not arise), the difficulty of obtaining land, and the high price to be paid for it, will always stand in the way of wide irrigation. To compensate for the limitation these obstacles will impose, it must not be forgotten that the produce of sewage farms loses much of its value directly it overreaches the home market, and with a large area used for irrigation in the neighborhood of a town this may be easily done. Already we hear of the produce of the Warwick Sewage Farm being sent to Birmingham, and that of Romford to Liverpool, and various instances of a like kind might be mentioned. One great advantage in the adoption of intermittent filtration, in the shape of concentrated irrigation, is that a greater variety of crops may be grown, and the over-stocking of the market with vegetables avoided, inasmuch as by giving each series of filtering areas a rest of a year or two, the growth of cereals and other crops, which are not successfully grown by ordinary irrigation, would take their part in rotation, and thus dispose of those manurial elements which might otherwise be left in the soil.

It would be too sanguine a view to suppose that the ratepayers of a district adopting the filtration process in its narrowest form would receive as much for their sewage as when irrigation is adopted under advantageous circumstances, in its widest form; but it is more than likely that, in a majority of cases, a better return may be gained from a medium course of action than from any other, though it is our duty, in a national point of view, to aim at making the most we can of the valuable matter with which we have to deal.

III.—*Separation of the Excretal Closet-matter from the Liquid Refuse of the Sewer, and dealing with each separately.*

As already stated, the treatment of the excremental contents of the closet separately from the liquid sewage of the sewers, is an object in which agriculturists must take a very great interest, though I have never yet met with any estimate of their value. Reverting, however, to the figures given as the value of the voidings of human beings, it would not be too much to take a fifth of the intrinsic value quoted (8s. 5¾d.), or 1s. 8½d. per head of the population, as the value of that which is retained in the closet, and which is capable of separate treatment, and is easy of removal to lands which cannot partake of the liquid sewage.

As the subject of this paper is limited to the fertilizing powers of sewage and the purifying powers of soil, it forms no part of my purpose to discuss the question whether town authorities act wisely in maintaining such a species of scavenging as is involved in the removal of the excretal refuse apart from the liquid sewage. I am, however, prepared to state that, having examined several dry processes now in use, there are some that may be adopted without objection, though it cannot be expected that the occupiers of superior houses, who have once enjoyed the comfort of well-supplied and well-constructed water-closets, should abandon the advantage and resort to dry closets of any description. At Rochdale, Alderman Taylor has patented a plan which is now in use there. Beneath each seat a receptacle containing a small quantity of a disinfecting fluid is placed, in which the fæces and urine are collected. The receptacles are removed in a covered cart weekly, or more frequently if required, to a manufactory on the outskirts of the town. There they are mixed with fine ash reduced from the cinders and dry refuse collected from the houses. The larger cinders, when separated from the ash, are sold. The average price realized for the manure mixture has been 17s. per ton, affording a profit after deducting all expenses, of 2s. 5d. per ton. At the price mentioned, the manure is readily sold, and I can well believe is of great value to the farmer, particularly for certain descriptions of grass lands.

In large manufacturing towns, where water is much required in the trade that supports the population, and where it is desirable to economize as much as possible its use, and therefore to avoid water-closets, Alderman Taylor's process has much to recommend it, and from personal observation I am able to declare that it is free from the many objections that attend badly-constructed and badly-managed water-closets. In fact, I examined many closets attached to cottages in Rochdale which were much more creditable than many of the water-closets attached to large establishments in the metropolis.

But whatever may be done with the excretal matter by dry appliances, it will not be possible to avoid the proper disposal of the sewage of the sewers, and that will still have to be done by one of the classes of treatment already explained.

In small towns and villages it is still to be hoped that the dry-earth system, invented by the Rev. Henry Moule, may be more generally adopted. The experience gained, however, shows that the frequency with which the closets get out of order, and the difficulty of supplying and removing the earth, is such that, unless a system of management is organized and enforced, they cannot gain much ground. Where there exists a proper officer, with assistants, if necessary, to supply the earth and remove the soil, and to keep the closets in working order, it is impossible that anything can be more suitable for isolated establishments and country villages; and when it is remembered that the difficulties of providing a public supply of water to villages are such as to be insurmountable in many cases, and that the leaky condition of the privy and cesspit maintains the soil in close villages in an excrement-sodden condition, resulting in the pollution of tank or well water, it does appear almost incomprehensible that the governing powers of this country should permit the continuance of the present state of things.

LAND AS A PURIFIER OF SEWAGE.

Having spoken of the general purification of sewage by land, when treating of irrigation and filtration, it is only necessary to add a brief description of the process of intermittent filtration, as it has been carried out under my directions at Merthyr-Tydvil. There 20 acres of land have been laid out for the purification of the sewage of the district, of which the dry weather flow at the time when the works were commenced amounted to 870,430 gallons per diem, the least flow during the day being 500 gallons; and the greatest 663 gallons a minute. The population contributing this sewage exceeds 50,000, but at present less than half the houses are connected with the sewers, so that the sewage may be taken as equivalent to the discharge of about 30,000 people. The number of water-closets being few, the sewage may be considered to be weak. Upon occasions of rainfall (which is above the average), the flow of the sewers is much increased, the storm waters frequently raising the discharge at least 50 per cent. above the ordinary dry weather flow, and this excess finds its way to the filtering areas. The 20 acres of land were divided into 4 equal parts, and before forming the surface to receive the sewage the whole was drained from $5\frac{1}{2}$ to $7\frac{1}{2}$ ft. deep, and deeply cultivated. By this means 2 cubic yards of soil for every square yard of surface became serviceable as filtering material, there being but very few rods of ground in which the full depth of 6 ft. was not secured. The quantity of filtering material was fixed upon so that the maximum quantity of sewage which would at any time have to pass through each cubic yard of soil would not exceed $7\frac{1}{2}$ gallons per diem, while the mean quantity of dry weather sewage would pass through at the rate of 5 gallons per cubic yard. The under-drainage was so designed that no sewage could travel over the surface directly above the drain, which is the case in instances of irrigation of free soils in which the results have not been so favorable.

Here the result has been the most complete purification of the sewage up to this time, and the realization of the fact that the effluent water from the under-drains was as pure when the whole of the sewage was passing through half the filtering areas, viz., 10 acres, as when it passed through 15 and 20 acres, showing clearly that a less number of acres than 20 acres would suffice for the purification of the quantity of sewage dealt with, and that therefore if the sewage had been double the strength or double the quantity, as it may ultimately be when the whole of the sewage of the 50,000 persons is discharged by the sewers, there will be a certainty of complete purification of the whole if the Board manage the works efficiently now they are completed.

During the period when the existing sewage, increased at times by the rainfall, was discharged upon the 10 acres (half the areas), they were receiving as much as 144,000 gallons per acre, which is equal to a depth of nearly $6\frac{1}{2}$ in., and never less than 72,000 per acre (equal to a depth of $3\frac{1}{4}$ in.).

Instead of following the mode of distribution usually adopted in sewage irrigation when the fluid is either run over a regular surface, or along the ridge to flow over the slopes on either side, the surface of the Merthyr filtering areas was laid out in the ridge and furrow form, as before explained, the object being to allow of the use of the horse and hand hoe, and while growing crops on the ridge to allow the sewage to flow in the furrows, and rise up to the ridge sides with a certainty of being absorbed, and of feeding vegetation at the same time. This treatment has been so successful that, in spite of the deposit of the finer particles of floating matter in the furrow, the whole of the sewage has disappeared within 4 or 5 hours after application, and the land has acted as a purifier up to this time in such a way that the effluent water from the under-drains is pronounced by Dr. Benjamin Paul to be cleaner than the Thames water above the intakes of the metropolis water companies. In order that its condition may be compared with the standard suggested by the

Rivers Pollution Commissioners, I here give the analyses of the discharge from the 10 and 15 acres, when the whole of the sewage was run through those quantities of soil :—

Results of Analyses in Parts per 100,000.

Solid contents—	Effluent water from 10 acres.	Effluent water from 15 acres.
Total	39.00	55.00
Fixed	34.00	34.00
Volatile	5.00	21.00
Ammonia	.082	.086
Organic matter	.018	.011

Though it is a subject of personal satisfaction to me to have been the first to test, by designed operations, the process of intermittent downward filtration, suggested by the Rivers Pollution Commissioners, and to prove by direct evidence that the objections they anticipated can be avoided, the result might have been expected from the circumstances that in every case where sewage has been utilized on land, and allowed to pass through the soil as well as over it, the effluent water has been perfectly satisfactory. This will be seen by the following analyses of effluent water discharged from lands which have absorbed the sewage without any overflow from the surface, and without being laid out for intermittent action, except in the case of Merthyr-Tydvil, which I have described.

Parts per 100,000 *feet.*

Date.	Place.	Total Solid matter in solution	Organic carbon.	Organic nitrogen.	Ammonia.	Chemical Authority.
1868:						
September 10	Bedford	76.8	.575	.163	.023	Rivers Pollution Commissioners.
" 23....	Carlisle	28.8	.591	.204	.025	" "
" 24....	Penrith	21.9	.320	.108	.001	" "
1870:						
July 9..........	Convalescent Hospital, Walton	10 87	..	.002	.002	Dr. Odling.
" 24..........	Breton's Farm, Romford	70.60	..	.037	.003	Dr. Russell.
1871:						
September 4....	Merthyr-Tydvil	39.00	..	.018	.082	Dr. Benj. Paul.
" 4....	Lodge Farm, Barking	91.3	.676	.198	.005	Dr. Frankland.
" 12....	Tonbridge Wells	34.44	..	.060	.03	Dr. Voelcker.

If the proportions of polluting matter indicated in these analyses are compared with those contained in the effluent liquid discharged from the chemical processes to which reference has been made, or even with those of the effluents from the surface of lands over which sewage has been passed, the superiority of the combined effect of filtration associated with irrigation must be acknowledged. And on a study of all the facts such comparisons will expose, it will be manifest to every unprejudiced mind that, not only is it possible for town authorities to conform to a high standard of purity, but that, with a comparatively small quantity of land at command, it is a simple and inexpensive thing to do.

If this be true, ought there to be any hesitation in adopting a standard so high as to remove all doubt on the subject, with compulsory powers to enforce it?

We have had mournful proof that polluted water will find its way into the palace of the powerful as well as into the cottage of the poor; and our Society has special reasons, in the very serious illness of our Royal President, the Prince of Wales, which has aroused the anxiety of the whole nation, and which is said to be traceable to impure water or sewer gases, for exerting all the power it possesses in preventing the public interests being sacrificed to the influence of water companies, and the false notions of economy which prevail with local Boards of Health.

HYDRAULICS AS AN EXACT SCIENCE.

By H. HEINEMAN.

Translated from "Zeitschrift des Vereines Deutscher Ingenieure."

It is not our purpose to give a complete history of the origin and progress of the science of hydraulics, but to examine its present condition. The essential results of the experiments and investigations of engineering authorities are recorded in our modern text-books. Of these the works of Weisbach and Rühlmann have the widest circulation.

In referring to these works in the course of this criticism, though we recognize the valuable contributions of their authors to hydraulic science, we shall expose and attack their errors. We fear that we have before us an ungrateful task; but in undertaking the demolition of a decayed, falling structure we are clearly determined what to set up in its place.

We begin with the flow of water from vessels. It is not to be denied that this is the section of hydraulics in which a theory has been deduced from experiment that leaves the least defect to be supplied; and for this great credit is due to Weisbach. Still, in almost all cases in which this theory attempts to establish itself upon a rational foundation of observed elementary phenomena, it comes into conflict with both the experience of the practical man and the simplest and most certain of the laws of geomechanics. Whenever it has fortunately avoided these rocks it usually follows that it reasons in a circle, and achieves only an apparent demonstration.

All the elementary works on hydraulics introduce the science with the attempt of John and Daniel Bernouilli, to deduce a rational formula for the velocity of discharge from an orifice in the bottom of an indefinitely large vessel; which gives a result contradictory to the elementary conceptions of force, mass, acceleration and mechanical effect. Upon this the whole later superstructure rests in a greater or less degree, so that the necessary result is an inextricable tangle of obscurities and inconsequences. It is impossible to do more than make a rough conjecture as to the forces, accelerating and retarding, which determine the motion of water. We hardly refrain from expression of our wonder when we see to what resorts hydraulicians have been driven in their attempts to establish in diverse ways their untenable theories. Rühlmann begins his deduction on a correct geometric basis, if one overlooks his hypothesis, entirely contrary to fact, that the different layers of water in a vessel can descend with different velocities without losing their primitive relative connection, or partially mingling, so as to lose their original identity. He thus obtains for each element, for a fall h, a velocity $v = \sqrt{2gh}$, but leaves undetermined how many such elements are discharged in a unit of time.

Weisbach begins his proof with an assumption nearer the truth: that the prism ah, which at first rests over the opening a, is set in motion by the action of gravity. This prism is hindered from free falling only by its cohesion with the surrounding water. This cohesion also acts as a resistance to discharge. Neglecting this, and regarding the descent as free, so that it is continually maintained at the height h by the supply, we find that a column ah falls from surface to orifice continuously, and the centre of gravity must descend a space $\frac{h}{2}$ below the bottom of the vessel in order that it may describe a space h. That which is true for the column ah must hold for n successive columns, and therefore for the quantity Q discharged in a second. In order that this may absorb the mechanical effect $Q\gamma h$, either the mean depth must increase the space $\frac{h}{2}$ by an additional $\frac{h}{2}$, or a second depth or head h must act in addition to the head h of the water in the vessel. Weisbach's investigation unconsciously assumes this when it determines that the mechanical effect of the quantity of water discharged from an orifice of area a in the thin bottom of a vessel is $Qh\gamma = avh\gamma$, instead of $\frac{1}{2}$ this value. Hence Weisbach's method conducts us, not to the velocity of discharge from an indefinitely large vessel, in which the surface of the water is at rest and in which the initial motion must be continuous; but to the velocity of discharge from a vessel into which water enters with a velocity equal to that of the discharge; as, for example, from an orifice under the head Q $a\,h\,\gamma$. In this case we have the correct formula.

$$v = \sqrt{g\,(h+h)} = \sqrt{2\,g\,h}.$$

It corresponds also to the free fall of a water-prism in a vessel of constant cross-section whose orifice-area is equal to the section—*i.e.*, a tube. The same result should be obtained from the formula of Bernouilli (by making $A = a$)

$$v = \sqrt{\frac{2\,g\,h}{1 - \frac{a^2}{A^2}}}$$

in which A is the cross-section of the vessel, and a the orifice-area. The pure mathematician is alarmed when he finds that this condition makes v infinite, although his data have been determinate and finite; for the length of the tube h and the area $A = a$ may be taken very small, and the Atlantic Ocean may be assumed as the source of supply at the upper orifice. The solution of the riddle is found upon a critical examination of Bernouilli's formula. Besides the fundamental error, we find a lack of precise discrimination as to the question whether the supply-water owes its velocity to the height h, or to some other head external to the vessel. Correcting the error, we have

$$v = \frac{\sqrt{g\,h}}{\sqrt{1 - \frac{1}{2} \cdot \frac{a^2}{A^2}}}$$

a formula very similar to that of Bernouilli, and, within certain limits, giving results nearly, if not exactly, the same, but differing from it when $a = A$; for in this case it gives $v = \sqrt{2\,g\,h}$, which correctly expresses the fact, that under this hypothesis the water must fall without hindrance through the tube, there being no molecular resistances; or that it enters the tube with an initial velocity equal to that of discharge.

When we examine the superstructure upon this insecure foundation, we find that it resembles a stone-heap of disconnected pieces, brought together by experiment, with mortar joints outside, but without organic bond. The primitive law determining all phenomena of discharge is wanting. For it, has been substituted a great number of empirical coëfficients, obtained from separate and combined observations. The selection and combination of these with reference to practical needs, so as to compensate, as far as possible, for the want of a rational law, must be credited to Weisbach. But there is, as in every empirical theory, a limit to the range of the coëfficients, which must be approached with caution.

With the exception of the principles of the Bernouillis, we find no independent attempt to deduce rational laws for the theory of discharge, and the relations of hydromechanics to geomechanics. We find, again, that such laws are assumed in the theory of the power and resistance of fluids. Let us see if this assumption is well made.

In Weisbach, §420, after a long investigation, we are led to this principle: "The reaction of a horizontal stream is equal to the weight of a column of water whose base is the cross-section, and whose altitude is twice the height due to the velocity." We hope at some future time to be able to dispense with a special proof of this principle, for the reaction upon the posterior surface obviously cannot be anything different from that which the water exerts at the orifice of discharge in the anterior wall. But the force must be exactly equal to that which the velocity of discharge v, through the orifice a, can produce; that is, to the weight of a column of water having a base a and a height $\frac{v^2}{g}$, or a base $2\,a$ and a height $\frac{v^2}{2\,g}$, which signifies double the height due to the velocity. Every other attempt at proof must either overlook this simple geomechanic principle, or, so long as the fundamental error is not corrected, must be merely an attempt to compensate for one error by introducing another, so as to obtain a result which agrees with facts. Let us seek for the error, and its cover in Weisbach's method. For this, the lateral motion serves, which the vessel must make during the efflux with the velocity v, without influence upon the result, because v appears in the proof only to disappear as soon as it has done its duty. But this duty it has done but imperfectly; for, after it has been certainly shown that C_2

stands for the absolute velocity of the water on entering the vessel, we again come to this conclusion: "But the mechanical energy of the water before discharge, and therefore on entering the vessel, is

$$L_1 = \left(\frac{C_2^2}{2g} + h\right) Q \gamma."$$

Hence the mechanical energy, $h\ Q\ \gamma$, which is due to efflux under a head h, is already assigned to the water when it enters the vessel. In the progress of the investigation, it happens that in consequence of the error the estimated difference of the energy before discharge *minus* the energy after discharge—in other words, the amount of reaction—has a positive sign, while anyone would expect it to be negative. Correcting this error, by rejecting the erroneous h, and making the arbitrary lateral velocity of the vessel equal to zero, we have more simply and quickly $L_1 - L_2 = -h\ Q\ \gamma$, which is the work of reaction. It is only necessary to divide this by the constant velocity C, remembering that $\frac{Q}{c} = a$ the orifice area, to obtain the reactive pressure $Z = -h\, a\, \gamma$.

But $h = \frac{c^2}{2g}$ signifies the simple height due to velocity. But the problem was to obtain $-2\, h\, a\, \gamma$, which got the negative sign by the doubling referred to.

Again, the next principle is this:

"The normal impulse of water against a plane surface is equal to the weight of a column of water having for base the section of the stream, and for height twice the height due to velocity

$$= 2\, h = \frac{2\, c^2}{2\, g} = \frac{c^2}{g}."$$

We have as little need as before for proof, as soon as it is shown that $\frac{c^2}{g}$ is not twice the height due to the velocity, but the exact height itself. The force which acts against the vessel clearly must be the same as that exerted against the stream, and this is $\frac{c^2}{g}\, a\, \gamma$; a being the sectional area, and γ the unit weight. Let us again seek for the covering error.

Weisbach (§§ 498, 499) supposes a surface of revolution, with an inclination a to the axis of the stream. He supposes the stream to issue with a velocity c, while the surface yields with a velocity v, in the same direction; and he proceeds with the assumption that the stream moves along the surface with a velocity equal to that of the first impact. A condition is again assumed without proof, which in our judgment requires demonstration quite as much as the principle sought to be established. Then follows a correct and logical deduction, which, however, has not the remotest relation to the actual phenomena of impact of water. An arbitrary quantity Q, of weight $Q\,\gamma$, meets the surface with a certain velocity in a certain direction. The result is correct, viz., that the force of impact is the quotient of the velocity into the work.

$$P = (1 - \cos.\ a)\ \frac{c^2}{g}\ Q\,\gamma.$$

This purely geomechanic equation holds for any value of c or of Q, and is independent of the duration of impact. But Q is a function of the time of discharge, and without determination of this, is an indeterminate magnitude. In 10 secs. there is impact of 100 times as much as in $\frac{1}{10}$ of a sec. Hence we can as correctly put Q equal $\frac{a\,c}{n}$ as $n\,a\,c$, and though velocity and orifice remain constant, can vary it from zero to infinity. It is therefore purely accidental that P takes a value agreeing with its actual value, when we put $Q = a\,c$, the amount of discharge in a second.

This indefiniteness of the conceptions introduced into the investigation is shown when we put $v = 0$; that is, assume that the surface is at rest; and $\cos\ a = 0$, that is, suppose the direction of impact to be normal. We then find the work expended on the surface $P\ v = 0$. Dividing both members by $v = 0$, we have $P = \frac{0}{0}$. It follows that impact against a surface at rest is an indeterminate magnitude, while it follows from the equation $P\ v = 0$ (though often hitherto doubted), that a stream of water impinging on a surface at rest, suffers no loss of living force on account of the impact. This result is by no means proven, and was regarded as not proven, in the assumption that the stream leaves the surface with a velocity equal to what it had at first impact.

We find an attempt at rational proof of the same principle in § 163 of Rühlmann's book. In this the actual phenomena are considered. The stream of water, according to the author, forms a cone equilibrated on all sides with base on the plane and vertex in the stream. If the plane is large enough, the side of the cone forms a quadrant of a circle to which stream-axis and plane are tangent. Unfortunately this proof also begins with a hypothesis not proven, that the stream spreads over the surface with a velocity equal to its initial value. The resistance (which the plane must exert in order to cause this deviation from the original direction of the stream) is now correctly determined. In geomechanics the theory of centrifugal force gives the fundamental formula

$$P = \frac{m\,v^2}{r}$$

From this is correctly found, for constant pressure on the surface,

$$P = \frac{v^2}{g}, a\,\gamma\,\frac{K\,L}{2\,r}.$$

K L and 2 r are magnitudes determined neither by probable hypothesis nor by experiment; namely, the diameter of the base of the cone, and twice the radius of curvature of deviating stream. We have only to assume

$$\frac{K\,L}{2\,r} = 1$$

to obtain the desired result

$$P = \frac{v^2}{g}.a\,\gamma.$$

By actual experiment we meet the surprising fact that, independent of the velocity, the diameter of the stream is to that of the base of the cone as 1 : $\sqrt{2}$; while K L : 2 r at the outer edge of the stream as 3, 5 : 1, and at inner edge as 2 : 1, so that $\frac{K\,L}{2r}$ varies from 3.5 to 2.

In view of this, of what value is this laborious investigation? Taking in the process of proof at a glance, we find that it is an able but discursive treatment of this simple question: "What power must act continuously in order that in every second of time a quantity of water, Q, moving with a velocity, v, shall be made to deviate from its original direction by the angle a?" Geomechanics solves this problem without assumption, and by synthetic combination of its most elementary and incontrovertible principles.

In the theory of the impact of water no attempts at demonstration have been made to which the hydraulic engineers of our time assign more than a conjectural value. The like is true of the theory of the motion of water in tubes and in streams; yet it may be of interest to take a brief survey of the progress which efforts in this direction have achieved, and of the standpoint which they have so far reached.

If one attempts to derive the phenomena of motion of fluids from the well-established laws of geomechanics, and in so doing commits an error, and then attempts to reconcile the discrepancies by hypotheses about the magnitude and nature of resistances, the investigation of these resistances must be very difficult because of the false steps taken in the course of reasoning. Although he may admit that resistances which oppose the free fall of water must depend exclusively upon cohesion and adhesion, still he cannot rise to the conception that in this matter we have to do with molecular forces, which are entirely independent of the circumstances of motion of the masses, being variable only as functions of the temperature, and of conditions of aggregation, but invariable between two molecules of the same chemical and physical constitution. It is admitted that two entirely different forces oppose motion, one of which increases as the first power, the other, as the second, or some other power, of the velocity of the water. This is correct, for only under this condition can we maintain the hypothesis of a uniform motion of water, without contradicting other phenomena of the visible world.

Uniform motion in an absolute sense is merely an ideal conception of writers on mechanics, who make use of it to fix the notion of the differential of velocity or space in case of variable motion. Nature recognizes only uniformly accelerated or retarded motion, utterly abhorring that which is constant. Whenever a body is left to itself and not guided along artificial channels, we can discern no case in which the path described is either straight or circular. Gravity, by means of its continual resistance, prevents persistence in uniform motion along natural paths.

If the accelerating force is equal to the retarding resistance, no motion ensues, or that only is maintained without change, which the mass possessed before the action of the force and resistance began. Any excess of one over the other can manifestly cause only a continually varying motion.

If we suppose that we thus find an apparent contradiction between geomechanic and hydraulic laws—as, for example, in case of motion of water in tubes—we have not attained a clear conception that the amount of motion is generally a function of two factors, the mass and the velocity, and that increase or decrease of motion may be the consequence of the increase or diminution of either or both of these. Geomechanics has made us accustomed to a certain one-sidedness of view, since it generally represents the mass as invariable, and the velocity as changing. Hence we need an extension of our usual range of views, in order to solve the problem before us; and in the lack of this we must seek for the reason that all previous attempts in this direction have been abortive. The simpler and more closely connected the forces of nature in the primitive constitution of a body, the more manifold and complete are the phenomena of production of energy. We find modern science continually attempting investigation in the primitive constitution.

So far, mechanics has developed only two fundamental principles to apply to all known phenomena of nature. One represents the measure of the magnitude of a constant force, P, by the product m, p, of the mass into the increment of velocity (acceleration) in a unit of time. The other represents the work done during a time, t, by the product $P s$, of the force and the space described. From both these principles it follows that the magnitude of the mechanical work done or absorbed in a given time does not give the least clue to the determination of the magnitude of the force acting. For the same force P we may put either $n \cdot \frac{m p}{n}$ or $\frac{m}{n} p n$.

In the first case the work done in the time t is $P s = \frac{m p^2 t^2}{2 n}$; in the second, $P s = \frac{n m p^2 t}{2}$. Putting $n = \infty$, the work in one case is infinitely small, in the other, infinitely large. In none of our geomechanic operations have we had opportunity to make this relation clear and precise to our understanding, because these always deal with constant mass and varying velocity, while in all hydraulic investigations, without exception, the mass set in motion either increases or diminishes along with the acceleration, or in case of constant acceleration, is itself variable. The first case corresponds to constant section profile and variable head; the second to constant head and variable profile. We therefore err, if we infer an equilibrium of accelerating and retarding forces, from the fact of constant velocity in the motion of water. Motion under the operation of constant forces may be continually varied as well by setting new masses in motion with constant velocity, as by giving to the same mass a constant increment of velocity. The first case corresponds to the motion of water in tubes, and discharge from orifices of vessels; and the continually acting surplus of accelerating force in this case produces a determinate and constant work, since during each unit of time a velocity, v, is imparted to a mass, Q, which was at first at rest in the vessel. Where, hitherto, we have understood v to mean the constant velocity of a uniform volume in motion, we really had to do with nothing more or less than the acceleration p, of a constant force, P. To this change of conception correspond the device of making the resistance increase as some power of the velocity, and the assumption of a new error to compensate for the former.

Still, within certain limits we have approached very near the true law by means of empirical coefficients, because we have generally worked with a certain head in the correct ratio to the acceleration; and with a certain limitation of length and section-profile of wet perimeter in a correct ratio to the retarding force.

Looking closely at the experiments which have been made during the last century by hydraulic engineers, with great labor and generous outlay of means, and especially at the measurement of the resistance of the walls of pipes, we must reach one conclusion. There was need only of a smooth tube with small orifice, set exactly perpendicular to a lever or spring balance. Let streams of water which fill the tube and flow with different velocities pass through it; then the index must show exactly in pounds and ounces the amount of cohesion and adhesion; in other words, the resistance offered by the tube.

With the conviction that the resistance increases in a direct ratio with the length of the tube, we come to the law of motion of fluids in channels of indefinite length. If we find our hypothesis for flow through tubes in agreement with the general law of Nature to the same extent as in the previous case of a supposed constant surplus of force, which acts in a discharging vessel so as to maintain a constant motion, we meet with the inexplicable anomaly that the water which runs uniformly, already has this velocity at the entrance of the channel. Hence we may look upon this case as the continuation of a motion already existing, without loss or gain of mechanical effect.

Dubuat's principle, that "when water moves uniformly in open canals, the resistance is equal to the moving force of the water," was obvious, so that it needed no demonstration. But the total moving force of water in a channel of length l, relative fall $\frac{h}{l}$, and section profile [illegible] is entirely independent of the length, since it may be expressed as that of a heavy body on an inclined plane ; *i. e.*, it equals $a\, l\, \gamma$ sin. a or $a\, l\, \gamma \frac{h}{l} a \gamma h$, while the force of resistance is a function of the length l of the form $\mu \frac{a}{l} . l$. What significance must nature have to one who can represent this false relation by a certain and determinate variability of the factor $\mu \frac{a}{p}$, or of the quotient $\frac{h}{l}$. It is possible that in a single case, calculation would give a true result ; but the probability of this is so small, that it is doubtful whether in all Europe there is a single stream that would give such a correspondence. So in following up to the present time the methods of determining a velocity formula, which will answer for all channels of indefinite length, we find that the search is for a law that cannot exist without contradiction of our ideas of natural forces which we have derived from experience. In this respect we find that the old French authorities followed a much more correct method than their successors; for in the well-known 31 experiments of Dubuat at Courpatel, at Yard, and on the Haine, we find exact length dimensions given, while these get no attention in modern experiments. Even the latest results of Humphreys and Abbott on the Mississippi, do not give length dimensions, and are therefore without value for the further development of the science.

A second circumstance—which is of more import in the motion of water in tubes than in river-channels, and of little consequence in the discharge from vessels, and which impairs the usefulness of all results from experiments hitherto—is the effect of temperature upon the resistance to fluid motion, an effect so far unknown.

The question whether this is a problem admitting of exact solution, must be decided in the future. There remains to be solved another problem, seeming at least still to be more difficult of solution, before hydraulics can become an exact science; that is, finding the relation of the work of resistance to accelerating force and to acceleration. We find nothing analogous in the whole range of mechanics, to assist in the determination of this relation. We go beyond our original intent in this article for a brief consideration of this subject.

Let us assume that water flowing from a vessel, A, into a vessel, B, with a level lower by h, through a tube of length, l, section a, and wet perimeter, p, is subjected to an accelerating force $P = a\, h\, \gamma$, and to an opposing retarding force, R, smaller than P. The excess P—R causes a certain discharged mass $m = \frac{a\, v\, \gamma}{g}$ during each unit of time to change from rest to motion and to acquire the velocity v. Hence we have the fundamental equation $v = \frac{P - R}{m}$ (1) *i. e.*, the algebraic sum of the forces divided by the mass.

Now let us assume that it is possible to measure and express in numbers the total internal and external work of resistance performed by the water while discharged through the vertical tube fixed to a balance as above described, and to represent it as the product $A_r = W\, v$ of a certain resistance, W, and the mean resistance of the water ; then the problem of finding v from equation (1) would seem to be solved if we could express the unknown resistance, R, which P opposes, to the mass m, by A r. It may be asked, what can this R be other than $\frac{A_r}{v} = W$, the resistance that describes a path, v, in a unit of time?

This ideal force R, which we will suppose to be measured by an ideal acceleration, r, which it can impart to the mass m, is not $= W$, but we have

$$R = \sqrt{2\,m\,A_r} = \sqrt{2\,m\,W\,v}. \qquad (2.)$$

That is, it must fulfil the condition, that its effect upon the motion of discharge during each infinitesimal time element, $d\,t$, shall destroy the work of resistance or generate its equivalent. If this work, during the time-unit is $A\,r$, and is proportional to the space described in the same time by the discharged mass, then, during the time $d\,t$, the work is $A_r\,d\,t$; but the work done by the force, R, is that which gives a mass, m, a final velocity, r, that is $\frac{m\,r^2}{2}$, hence for the time, $d\,t, \frac{m\,r^2}{2}.d\,t$; since r and v must be regarded as constants, and the mass discharged as the only variable equivalent to the product of section velocity, and time.

Equating both expressions for work, we have

$$A_r\,d\,t = \frac{m\,r^2}{2}.\,d\,t.$$

or

$$A_r = \frac{m\,r^2}{2} \qquad (3).$$

which holds for any time, and therefore for the time-unit. But since $R = m\,r$ substitution in (3) gives

$$R = \sqrt{2\,m\,A_r} = \sqrt{2\,m\,W\,v},$$

which was to be proven.

If we obtain the coefficient of resistance ρ, by which $\sqrt{2\,g\,h}$ should be multiplied to give the effective velocity for every sort of motion, after finding the value of W, we have this relation to the cardinal equation, which solves all hydraulic problems.

$$\rho = \sqrt{1 + \frac{W}{4\,a\,\gamma\,h}} - \sqrt{\frac{W}{4\,a\,\gamma\,h}}.$$

Expressing the resistance of the wetted walls by $\mu\,p\,l$, and assuming that μ at 13 deg. R, is 0.52 lbs. for the surface-unit of a square foot (Prussian standards), the work absorbed in overcoming resistance is $W = 0.52\,p\,l\,h\,\frac{2}{3}$, and is therefore a function of the head h, of the form h^x; and, contrary to previous assumptions, is entirely independent of the effective velocity, V. With these formulas we find an agreement in the results of experiments which cannot be shown by any previous empirical formulas.

We thus obtain instead of Egtelevein's empirical formula for motion in canals and rivers, which is generally written

$$v = 90.9\sqrt{\frac{a\,a}{p}}$$

this formula

$$v = 86.08\sqrt{\frac{a\,a}{p}}\sqrt[6]{a\,l}$$

The small valuable factor $\sqrt[6]{a\,l}$, the difference of levels between A and B, explains why Egtelevein's formula has ordinarily (but by no means in all cases) given correct results, and approaches most nearly to the actual law.

CEMENT MANUFACTURE IN INDIA.

From "Engineering."

An order has recently been issued by the Governor-General of India on the subject of cement manufacture in that country, from which it would appear, at first sight, that no important works requiring anything more than ordinary mortar had ever yet been constructed there, excepting with cement obtained from England. What, however, we may ask, is to be said with reference to the old buildings, Hindoo, Mahomedan, Dutch, and Portuguese, all over India, under all varying circumstances and climates, which have been constructed with so excellent a cement that the masonry will break anywhere rather than at the joints, although the bricks, as well as the mortar, are stronger than any that are made now? Then, again, even since the British occupation of India, there are to be found works in the construction of which hydraulic and other cements have been required to be used, and which have hitherto stood the test of time, and may, therefore, be presumed to have been efficient for the purposes for which they have been employed. It is true that recently, and especially in the military department, it has been customary for buildings erected at enormous cost to fall down almost as soon as built, and the defective part of the construction has generally been the cement used. The exposures, however, which have taken place in connection with some of these failures tend to prove rather that the causes of them have been, not the absence of all knowledge of how to make cement in India, but rather the existence of a reign of negligence, corruption, and adulteration, coupled also occasionally with incapacity. The remedy for these defects is, therefore, not the introduction of a new and improved manufacture of cements in India, but the eradication of those evils from the Department of Public Works to which we have just referred.

Had there existed no publications in India on the subject of native cements used on her public works, there might possibly be some slight excuse for the officers of the secretariat, supposing that the art of cement manufacture had been already lost to India; but even that fact would not be sufficient to excuse the chief officers of the executive branch of the Department for their want of knowledge in that respect, for surely a knowledge of cement manufacture must in every country constitute one of the most important branches of knowledge of the civil engineer, and more especially is this the case in a country like India, where very often, in the case of large works, all the cement required has to be manufactured on the spot, all the lime burned, and all the bricks required made under the immediate superintendence of the engineer in charge. Departing now from speculative considerations, let us see what information may be derived from Indian publications, a reference to which might perhaps save the several local governments from the necessity of appointing officers specially to discover for them what has already been published. We have not thought it necessary to search back very far, confining ourselves strictly to well-known professional works, in order to arrive at an amount of information on this subject which will doubtless be found of much value and interest to those concerned in the construction of public works in India. At vol. i. of the "Professional Papers of the Madras Engineers" (published in 1839), pages 28 *et seq.*, will be found an interesting account of the manufacture and use of magnesia cement. In order to form the cement, the stone should first be broken up into small pieces, and then placed in a kiln to be calcined. During calcining the heat must not be raised to too high a temperature, otherwise the outside of the magnesia will melt, while the inside remains only half burnt. The most important thing, however, appears to be that the stone should remain in the kiln for at least 24 hours. After being thoroughly burnt, it should be pounded and sifted, and mixed with 1½ or 2 parts of sand. It must be thoroughly mixed with the sand while dry, and then moistened. "It will set in some degree in 2 or 3 hours, and become hard in a few days, after which it will continue still to harden, though slowly, for many months, or probably years." Some plastering, tried at the Cauvery Anicut by Captain (now Sir) A. T. Cotton, "became in a fortnight harder than any stone, except granite, marble, and stones of the first degree of hardness." Captain Cotton, in 1837, made a great variety of experiments with magnesia cement, using stone from various quarries, and with different proportions of sand, and other materials. Almost every one of them formed an excellent cement, setting generally in 1 or 2 hours sufficiently to be secure from the effects of water passing over it, but if plunged imediately in water, before it had begun to set, it would not set at all. It was observed by Captain Cotton that stone taken fron the surface of the ground was all extremely hard, while in general that found below the surface was much softer, though apparently equally pure, but hardened by exposure to the air; the cements made with the under stone were not found to give such good results as when surface stone was used. A mixture of iron ore with the magnesia in equal parts, both finely pounded and sifted, was found to make the strongest cement, and a mixture of lime and ironstone with the magnesia was also found to form a very hard cement. In forming cubes of brickwork, the magnesia cement was found to set very rapidly, "and in a few months it became so hard that it was impossible to separate it from the bricks; however small the cube was broken up, the bricks were always broken, without the cement being separated from them." A mixture of lime makes the cement less liable to crack when used as a plaster, but it will not set so hard.

In September, 1835, a committee was formed of engineer and medical officers at Madras, to examine a supply of calcined magnesia received from Salem, and to report on its fitness for building purposes. In their report it is stated as follows:

"The committee carefully examined portions of the magnesia cement on the walls of the superintending engineer's office, and on the sea face of the fort (in one of which, prepared from 3 parts, by measure, of sand, and 2 of the last supply of magnesia, salt was employed without injury), and find that they had acquired a great degree of hardness, although not fully equal to some specimens prepared from a former supply, which had been longer exposed to the air, and which had attained an extreme degree of hardness. It would appear, also, that a proportion of sand, amounting to about $1\frac{1}{2}$ parts, by measure, to 1 of magnesia, increases the usefulness of the cement for general purposes, bnt that this proportion may be increased or diminished, according to the view with which it is employed. When applied as an hydraulic cement it should not be subjected to water for upwards of 12 hours from the time of its application."

Turning now to the "Roorkee Treatise on Civil Engineering," vol. i., page 70, we find that Major H. A. Brownlow, R.E., Superintendent Eastern Jumna Canal, in a case where some urgent repairs were required, made a most excellent cement from the stone lime and brown alluvial clay procured near the head of the canal, following General Pasley's rules for mixing and calcining. Hydraulic cement has also been made with considerable success in Madras and at Singapore. Lieutenant Morgan on the Eastern Coast Canal, 6 miles north of Madras, made cement of 7 measures of shell lime to 5 measures of clay, following closely Pasley's rules for mixing and burning it. If applied under water this cement hardened in 24 hours; if applied dry and water let on it in half an hour, it hardened in 8 or 10 hours. The same cement mixed with an equal quantity of soorkhee (pounded brick) hardened in 48 hours under water, or in 12 to 24 hours if allowed half an hour before the water was let on it. Captain Man, at Singapore, found he could make a similar hydraulic cement, of excellent quality, using 5 measures of slaked lime to 2 of fresh blue clay. Natural hydraulic lime may be made from all the kunkurs found in India, but they will of course be found to vary in character with the different proportions of clay found in their composition. It is a common practice in India to mix a small quantity of the coarsest sugar ("goor," or "jaghery," as it is termed in Madras) with the water used for working up mortar, and to this is attributed the fact that mortars made of calcined shells have stood the action of the weather for centuries, from their having this mixture of "jaghery" in their composition. Captain Man made experiments on bricks joined together by mortar consisting of 1 part common shell lime to $1\frac{1}{2}$ sand. 1 lb of jaghery was mixed with each gallon of the water with which the mortar was mixed. The bricks were left for 13 years; and after that time the average breaking weight of the joint in 20 trials was $6\frac{1}{2}$ lbs. per sq. in. In 21 specimens joined with the same mortar, but without jaghery, the breaking weight was $4\frac{1}{2}$ lbs. per sq. in. In the jaghery mortars the cohesion and adhesion were nearly equal; in the other the former was nearly double the latter.

In Sir Proby Cautley's admirable work on the Ganges Canal, he has not omitted to record the nature of the cement used by him in that undertaking. Referring, then, to that publication for the desired information, we find that in the construction of the Myapoor works, boulder masonry was laid with a cement composed of 1 part stone lime, 1 part soorkee, and 1 part sand, whilst with brick masonry the cement used was 1 part stone lime, and 1 part soorkee, and the whole of the works were stuccoed with a cement formed with the latter ingredients, and in the same proportions. In the Rutmoo works, which are built wholly of brick, the lime used in the cement was made from lime rock either burnt in the Dehra valley, or from lime boulders collected in the bed of the Ganges. The proportions of material used in cement were as follows:

Mortar		1 part stone lime, 2 parts soorkee.
Plaster	Inlet and dam piers	1 part stone lime 2 parts soorkee.
	All the rest of the work	3 parts stone lime. 2 parts soorkee.

Similar statements occur in the various parts of the Ganges Canal Report, vol.

ii., and in the third volume is a statement of the entire amount of lime used on all the canal works. In some experiments made at Roorkee to discover the best composition for an hydraulic cement, the bricks, the day after being joined, were placed at the bottom of the Ganges Canal, and exposed to a stream of nearly 3 miles an hour. The cements were made of old fat stone lime, which had been lying under a dry arch for 6 years since being burnt; this was slaked, mixed with 1½, 2, and 2½ times its own weight of ordinary brown clay, following Pasley's directions. The composition of 1 lime to 2 clay was found the best, and 1 lime to 2½ clay the worst. At the same time some fresh stone lime was ground and mixed ed up carefully with an equal bulk of ground soorkee; and the result of a number of experiments proved that although the mortar made of lime and soorkee set in the air as hard as that made of the lime and clay burnt together, yet it would in no case set when exposed to the force of the canal stream; while the cement after 14 days under water required a breaking weight of 10 lbs. per sq. in. to separate the bricks. Some very hard blue clay was afterwards obtained from Hurdwar, and mixed with fresh stone lime, very slightly, if at all, hydraulic, in the proportion of 1 lime to 2 clay; and balls were calcined and ground as before; of this cement 4 prisms were made 6 in.×2½ in.×2½ in., and after 26 days immersed in water were subjected to a transverse strain the bearing being 4 in. The average breaking weight of the prisms was 598.5 lbs.; the greatest being 675 5 lbs. This gives the value of C, the constant of strength for this cement=123, while for prisms of Roman cement 11 days old was only 150. The lime used in that part of India is derived from 3 sources: 1, boulder limestones found in the beds of hill torrents; 2, marl, or earth lime, as it is called; 3, kunkur lime. Analysis of the first two varieties:

Nature of lime.	Moisture expelled at 212°.	Organic matter and moisture.	Silicious matter and clay.	Carbonate of lime.	Carbonate of Magnesia.	Oxide of iron and alumina.	Total.
1. Marl lime.	1 44	1.27	49 80	37.01	2.79	7 69	100
2. Stone lime.	0.40	2.43	11.18	50.43	23.73	11 83	100

The kunkur lime is similar to No. 2, both differing widely from stone lime. All make excellent mortars for hydraulic works; the ordinary mixture with No. 1 lime being 1 part stone lime to 2 of soorkee, or 140 lbs. lime to 400 lbs. soorkee, and if the mortar is to be used for ordinary building, 1 lime, 1 soorkee, and 1 sand may be used. With the marl lime, 1 of lime to 1 of sand, without any soorkee, is used.

Part of the foregoing particulars is taken from vol. iv. of the "Professional Papers on Indian Engineering," published at Roorkee. At page 192 of the same volume we find an account of the process of manufacture of artificial hydraulic lime on the Kurrachee harbor works. Ordinary rich lime slaked to powder, is mixed with clay, in the proportion of 5½ parts, by measure, of lime, to 1 part of clay. The rich lime used in the harbor works has been generally made from the hard crystalline limestone procured from the Giznee hills, near Kurrachee (shell-lime would probably be found a tolerable substitute where limestone is not easily available). The clay is procured *in situ* from the bed of the Lyaree river, and is of the description that might be used for bricks or coarse pottery. The mixture of the lime and clay is made in a mortar pan worked by steam power, a sufficient quantity of water being added to bring it to the consistency of a stiff mortar. The mixture is then made by hand into balls of about the size of a large orange, which are laid out on the ground to dry in the sun. When thoroughly dried, which takes from 2 to 6 days, according to the weather, the balls are burned in a kiln; or if the lime is not likely to be soon required, they are stored in a shed. It is most important that the balls should be thoroughly dried before burning."

Vol. v. of the same series of "Professional Papers," contains, at page 385, an account of experiments on mortar made by Lieutenant J. L. L. Morant, of the Royal (Madras) Engineers, during the construction of the masonry forts in Bombay Harbor. We have already stated enough to show that information does already exist, in an available form, as regards the limes, mortars, and cements of India; it will not therefore be necessary to follow out these experiments here. The fact is—not that the information recently called for by the Indian Government is wanted;

but rather the means of enforcing more vigilance in the inspection of materials obtained by contract for building purposes, so that fraud and adulteration may be certain of detection and punishment; that incapacity in the Executive may meet with its proper reward; and that neglect of duty may not be practised with impunity.

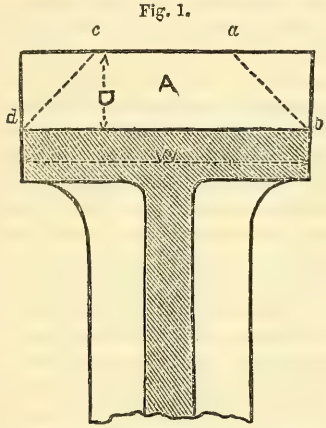
STRENGTH OF SPUR WHEELS.

By FRANCIS CAMPIN, C. E.

From "The Artizan."

In the present paper we purpose making some remarks upon the strength of mill-gearing, in order to set forth the principles upon which machinery of this description should be designed.

Fig. 1.



Let A, Fig. 1, represent a section of the rim of a spur-wheel taken over one of the areas, it is required to calculate the strength of the teeth of the wheel.

According to the old fashion it has been customary to calculate the strength on the line *a—b*, or *c—d*, as the whole strength of the wheel; but if this were correct, the lines being at an angle of 45 deg. to the face of the wheel, it is evident that it would be useless to make the width more than twice the depth of the tooth.

It is well known, however, that wheels very commonly lose the corners from their teeth and yet continue to work well for years afterwards. In point of fact, the tooth of the wheel is a cantilever, and its theoretical form should be to taper in width from its base *b d* to its point. Although we have heard it asserted that the strain upon the tooth of a wheel is neither more nor less than a shearing strain —a statement which is fallacious on the face of it, as the strain must be of a bending nature, and the maximum strain being reached when the power is being transmitted through the extreme end or point of the tooth.

It is found that a cantilever of cast iron, 1 in. long, 1 in. wide, and 1 in. thick, breaks under an extreme load of 8,000 lbs.

To find the breaking weight of any given cast-iron cantilever loaded at the end:

Multiply the breadth in inches by the square of the thickness in inches, the product by 8,000, and divide by the length in inches.

Let w = breadth in inches.
D = length "
t = thickness "
W = breaking weight.

$$W = \frac{8,000 \times w \times t^2}{D}.$$

Example: Let $t = 2$ in., $D = 3$ in., $w = 6$ in.

$$W = \frac{8,000 \times 6 \times 2^2}{3} = 64,000 \text{ lbs.}$$

breaking weight.

In practice it is usual to make the working strain one-sixth of the breaking weight;

Let L = safe load.

$$L = \frac{8,000 \times w \times t^2}{6 \times D}$$

$$= \frac{1.333 \times w \times t^2}{D}.$$

Therefore

$$t^2 = \frac{D\,L}{1,333 \times w}$$

$$t = \sqrt{\frac{D\,L}{1,333 \times w}}.$$

Which is the proper rule for calculating the thickness of the teeth of spur wheels.

Let the force transmitted by a spur wheel be 10,000 lbs., the length of the teeth being 3 in. and the breadth 6 in., then—

$$t = \sqrt{\frac{\text{D L}}{1{,}333 \times w}} = \sqrt{\frac{6 \times 10{,}000}{1{,}333 \times 3}}$$
$$= \sqrt{15} = 3.87 \text{ in.}$$

It is, however, in many cases more convenient to calculate at once the pitch of the wheels instead of the thickness of teeth.

According to the Manchester scale the thickness of a tooth is equal to 0.45 pitch. Therefore, if P = pitch

$$\text{P} = \text{T} \times 2.22.$$

Therefore

$$\text{P} = 2.22\,t = 2.22\sqrt{\frac{\text{D L}}{1333\,.\,w}}$$
$$= \sqrt{\frac{5\,\text{D L}}{1333.w}} = \sqrt{\frac{\text{D L}}{266.w}}.$$

Let the force transmitted by the wheel be 4,000 lbs., the length of tooth 2 in., and the breadth on face 4 in., then the pitch will be thus found—

$$\text{P} = \sqrt{\frac{\text{D L}}{266.w}} = \sqrt{\frac{2 \times 4000}{266 \times 4}} =$$
$$\sqrt{7.5} = 2.73 \text{ in. pitch.}$$

If we could be always certain of having the wheels very accurately made, it would not be necessary to make one tooth carry the whole strain ; but as this exact workmanship cannot always be secured, we have for the sake of safety to consider the whole strain as possibly coming on the point of one tooth, and make the wheels strong in proportion.

We must now make a few remarks as to the shrouding of wheels. In this case we have undoubtedly, in addition to the strength of the tooth regarded as a cantilever, the resistance to shearing at each end where the tooth joins the shroud. Let us assume the teeth to be shrouded on both sides up to the pitch line, that is half way up.

Taking the first example where $t = 2$ in., D = 3 in., and $w = 6$ in., we found—

$$\text{W} = \frac{8{,}000 \times 6 \times 2^2}{3} = 64{,}000 \text{ lbs.}$$

breaking weight merely regarding the tooth as a cantilever. Now, we have shearing area to the extent of half the length of the tooth multiplied by its thickness and by 2, there being a shroud on each side of the wheel ; hence the shearing area will be—

$$1.5 \times 2 \times 2 = 6 \text{ square inches.}$$

Taking the shearing resistance of cast iron at 17,000 lbs. per sectional square inch, the additional resistance afforded by the shrouding will be—

$$17{,}000 \times 6 = 102{,}000 \text{ lbs.}$$

or nearly twice the strength of the tooth itself.

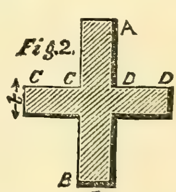
In any case it may safely be assumed that shrouding the teeth double their strength, and in most cases it does more than this.

Having determined the strength of the teeth, it becomes necessary to find a law for the strength of the arms of wheels through which the strain is transmitted from the rim to the shaft, or *vice versâ.*

It will be observed that the strain will not be constant on all the arms, as those nearest to the teeth in action will be the most strained, and the strain will diminish on the following arms, so that the strain on any one arm will always be varying.

If the rim of the wheel were perfectly hard and inelastic it stands to reason that the strain would be equal on all the arms, but this not being the case the strains vary according to the compression or extension of the rim.

For all practical purposes we may assume that the maximum strain that will come on one arm is one half of the total transmitted strain. Let the force transmitted be 10,000 lbs. on the teeth of the wheel, then on any arm there may come a force of 5,000 lbs., tending to break it like a cantilever.



In Fig. 2 is shown a section of an arm, but it might, of course, be of square, circular, or other section.

The direction of pressure is from A to B, or from B to A, and the force according to discretion is regarded as being withstood by the whole section, or by the parts A B only ; in the latter case the webs C C, D D, only act as lateral stiffeners to the wheel.

We will act upon the latter assumption; then A B is the depth of the cantilever, and its length is equal to the distance from the outside of the boss to the pitch-line of the teeth.

Let the length of the arm be 20 in. If W= the force acting at the end of the arm, t the thickness, d the depth, and l the length, then for the breaking weight we find—

$$W=\frac{8000\,t\,d^2}{l}$$

all the dimensions being in inches, and the force in tons.

And if the safe working load is taken at one-sixth of the breaking weight the formula becomes—

$$W=\frac{1333\,t\,d^2}{l}$$

from which the formulæ for depth and thickness are obtained.

$$t=\frac{W.l}{1333.d^2}$$

$$d=\sqrt{\frac{W.l}{1333.t}}=0.027\sqrt{\frac{W.l}{t}}$$

In the foregoing cases assume the depth of cantilever, or width of arm at the boss, as 8 in., then, the safe load being 5,000 lbs., and the length 20 in., we have for the thickness—

$$t=\frac{W\,l}{1333.d^2}=\frac{5000\times 20}{1333\times 8\times 8}$$
$$=\frac{100000}{85312}=1.17\text{ in.}$$

This applies to wheels having 4 arms.

If the wheel has 6 arms we may assume the maximum strain on any arm at one-third the total load, and the thickness would be—

$$t=\frac{W.l}{1333.d^2}=\frac{333\times 20}{133\times 8\times 8}$$
$$=\frac{66666}{85312}=0.78\text{ in.}$$

Suppose, however, in the first case (4 arms) it is decided to make the arms 3 in. thick, the requisite depth will be—

$$d=0.027\sqrt{\frac{W\,l}{t}}=0.027\sqrt{\frac{5000\times 20}{3}}$$
$$=0.027\sqrt{\frac{100000}{3}}=0.027\sqrt{33333}$$
$$=0.027\times 183=4.94=\text{(say) }5\text{ in.}$$

This then will be the requisite width of the boss, whence it may be diminished by any suitable taper down to the rim of the wheel, for the strain upon the arm is at its maximum where the arm joins the boss, and then diminishes to *nil* at the pitch circle of the teeth, and the strain on any part of the arm is in direct proportion to the distance of such part from the pitch circle. Thus at the centre of the arm the strain is half as great as at the boss, and so on.

For a different number of arms it may be generally assumed that the strain at a maximum on any arm is equal to the total force divided by half the number of arms.

Let P = pressure on teeth.
n = number of arms.
W = maximum load on any arm.

$$W=\frac{2\,P}{n}.$$

Let P = 5600 lbs., n = 5 arms,

$$W=\frac{2\,P}{n}=\frac{2\times 5600}{5}=2240\text{ lbs.}$$

The parts of the arm shown at C C, D D, in Fig. 2, do not add much to the strength of the arm to resist the stress of which we are now treating, as they lie too near to the centre or neutral axis of the cantilever.

Thus if these portions be 2 in. square each, they will together be equal to a solid cantilever 4 in. wide and 2 in. deep, and the portion A B has been shown to be 5 in. deep and 3 in. wide.

The transverse strength of solid beams (rectangular in form) varies as the breadth and as the square of the depth.

Let $b\ d$ represent the breadth and depth of one beam.
B D represent the breadth and depth of one beam.
R represent ratio of strengths.

$$R=\frac{b.d^2}{B.D^2}$$

in the present instance,

$$R=\frac{b.d^2}{B.D^2}=\frac{4\times 2\times 2}{3\times 5\times 5}$$
$$=\frac{16}{75}=0.21,\text{ or nearly }\tfrac{1}{5}.$$

There is another matter to be considered in connection with wheels, which is the effect of certain strains common to all rotating bodies, and caused by the centrifugal force which the rotation calls into action. This force acts primarily in a radial direction, but it may be resolved into tangential force; hence the intensity of it in its direct action can be ascertained.

First we will consider the rim of the wheel—

Let v = velocity of periphery in feet per second.
n = number of revolutions per minute.
d = diameter in feet.

w = weight per foot of rim in lbs.
a = sectional area of rim in sq. in.
c = centrifugal force in lbs.

Then for one foot of the rim we find—

$$c = \frac{w \times v^2}{16.1 \times d}$$

from the ordinary formula for centrifugal force.

We will treat this as a simple radial force tending to burst the ring, and call S the tensile strain on any section of the rim—

$$S = \frac{c\,d}{2}$$

but from the foregoing equation,

$$d = \frac{w\,.\,v^2}{16\,.1\,.c}.$$

Wherefore

$$S = \frac{c}{2} \times \frac{w\,v^2}{16\,.1\,.\,c}$$
$$= \frac{w\,v^2}{32\,.\,2}.$$

Then allowing 1,800 lbs. per square inch as the tensile working strength of cast iron the sectional area of the rim should be—

$$a = \frac{w\,.v^2}{32\,.\,2} \times \frac{1}{1800}$$
$$= \frac{w\,v^2}{57.960}$$

But from the specific weight of cast iron it is found that—

$$a = \frac{w}{3.2}.$$

Also,

$$n = \frac{60\,.\,v}{3.1416.d}$$
$$= \frac{19\,.\,v}{d}.$$

And therefore,

$$v = \frac{n \times d}{19}.$$

Whence by replacing in the various equations we deduce the limiting velocity for a cast-iron wheel working safely

$$n = \frac{2546}{d}.$$

NOTE.—For a wrought-iron rim it would be—

$$n = \frac{4427}{d}.$$

In the next place the strength of the arms to resist centrifugal force must be considered, as if the rim be flawed it will be held by the arms alone. The portion of the periphery of which the centrifugal force should be sustained by one arm, is that part lying between two arms.

Let a = sectional area of rim in square inches.
d = diameter of wheel in feet.
v = velocity in feet per second of rim.
A = area in square inches of one arm.
N = number of arms in the wheel.

Then because a 1 in. square bar of cast iron 1 ft. long weighs 3.2 lbs., the weight of the rim is

$$W = a \times 3.2 \times 3.1416\,d = a\,.10.d.$$

Hence the centrifugal force on all the arms may be

$$c = \frac{W\,v^2}{16.1 \times d} = \frac{10.a.d.v^2}{16.1 \times d}$$
$$= \frac{a\,v^2}{1.6}$$

But

$$v = \frac{n \times d}{19}$$

hence

$$c = \frac{a\,(n.d)^2}{577.6}.$$

The safe resistance of all the arms will be—

$$= A \times N \times 1800,$$

hence

$$1800.A.N. = \frac{a\,(n.d)^2}{577.6}$$

$$A = \frac{a\,(n.d)^2}{1{,}039{,}680.N}.$$

From these formula we can, for example, find the highest safe velocity at which the foregoing wheel could be run. The length of one arm being 20 in., its diameter would be 4 feet—

$$n = \frac{2546}{d} = \frac{2546}{4} = 636.5 \text{ revols. per minute.}$$

It is but seldom that spur wheels are run anywhere near their limiting velocities, but it is nevertheless necessary to consider the possibility of such cases arising.

As we have already observed, much depends upon the workmanship put into wheels, and before calculating for heavy mill work it is always advisable to inform ourselves of the average quality of work we may obtain.

Before concluding the present paper we will enter briefly upon the method of determining the maximum pressure on the tooth of a spur wheel.

It is very improper in all cases to calculate from horse power, for it may happen that at a certain position of the pistons the strain is much above the average

The moment of strain upon a revolving shaft is found by multiplying the strain by its distance from the centre of revolution.

Let the piston of an engine have a diameter of 20 in., then its area will be

$$= 314 \text{ square inches.}$$

A maximum pressure of 40 lbs. per sq. in. would give as gross pressure

$$314 \times 40 = 12{,}560 \text{ lbs.}$$

Let the crank be 2 ft. long, then as this force can never act at a greater distance from the centre of rotation than the length of the crank, the maximum moment will be

$$12{,}560 \times 2 = 25{,}120 \text{ foot lbs.}$$

If there be keyed on the engine-shaft a wheel of 4 ft. radius, the greatest pressure given off by one of its teeth will be found by dividing the moment of force by the radius,

$$\frac{25120}{4} = 6280 \text{ lbs.}$$

will be the maximum force on one tooth.

The pressure on one tooth of a driven wheel is the same as on one tooth of the driver.

If there are two spur wheels on one shaft—one (w) receiving motion and so communicating it to the shaft, and the other (W) giving it off to a fourth wheel, if p be the pressure of the teeth of w, and r and R the respective radii of the wheels, then the pressure P on the teeth of W will be thus found,

$$P \times R = p \times r$$

because the power being transmitted through the shaft unaltered, the moments of stress must be equal at both points of reception and distribution, hence

$$P = \frac{p \,.\, r}{R} \text{ or } R = \frac{p \,.\, r.}{P}$$

THE RAW MATERIAL FOR BESSEMER STEEL.

From the "Bulletin of the American Iron and Steel Association."

Although the manufacture of Bessemer steel has now become an established industry, the manufacturers are still confined to the use of ore of remarkable purity, and especially free from phosphorus; and taking advantage of the constantly increasing demand for ores of suitable quality, and the high prices obtained for them, an influential company (to which reference was made in last week's "Mining Journal") has been formed for working some extensive deposits in Spain, and shipping the ore to the English markets. The mere fact of some of the largest steel manufacturers and consumers of the purer qualities of ore accepting seats on the direction of the Bilbao Iron Ore Company should alone suffice to convince the public that ore of the desired quality is not readily obtainable at reasonable prices, within reach of the works at home; yet there appear to be some who, in their energy to utilize our native minerals, go a step too far, and assume that the importation of foreign ores is objectionable, and should be altogether discountenanced. It was stated in the prospectus of the company in question that the ironsides of South Wales, South Staffordshire and Scotland, are becoming exhausted, insomuch that the necessary supply for these districts has for many years been supplemented by the hematite ores of Cumberland and Lancashire; but owing to the great and constantly increasing demand for hematite pig iron for admixture with iron made from inferior ores, and the extension of the Bessemer steel manufacture, nearly the entire produce of hematite ores is absorbed by the iron works in the Cumberland district alone, and the price of these ores has advanced within the last two years 70 per cent., and hematite pig iron for the Bessemer process 50 per cent.

To such a statement there can be no valid objection, and if the Bilbao Company can supply the iron-masters engaged in the Bessemer steel manufacture with ores analogous to the Cumberland hematites, and yielding from 50 to 60 per cent. of metallic iron, no doubt need be entertained as to the facility of finding a ready market for them. With a view to depreciate the merits of the enterprise, however, attention has been drawn to mines alleged to exist in the forest of Dean and the West of England, which were described as being a closer proximity and more readily available, capable of producing superior ore, suitable for Bessemer pig iron; but fortunately Mr. Bessemer and Mr. Hardy of the Tredegar Iron Company, both equally unconnected with the Bilbao Iron Ore Company, have published the facts of the case. Mr. Bessemer knows the mines and the ore they produce; yet he writes that the Bilbao Iron Ore Company would have more correctly described the condition of the trade by stating that the greatly increased production of Bessemer steel has, within the last two years, doubled the price of hematite ore in England, and also greatly increased the price of pig iron made from it, and that the development of the Bessemer steel trade would be immensely increased by the introduction into the English market (at a moderate cost) of a further supply of hematite ore from Spain, a fact which Mr. Bessemer (being wholly unconnected with the Bilbao Iron Ore Company) can, without hesitation, most emphatically indorse; nor does he hesitate to affirm that the construction of a railway and a line of steamers connecting these magnificent mines with our own country, will be of almost incalculable benefit both to the steel and iron trade of the kingdom; while Mr. Hardy asserts as the result of his experience, that the chief supplies from the Forest of Dean and Cornwall are very poor ores, yielding only 30 to 35 per cent. of iron. This view is confirmed by Mr. Mattieu Williams, who explains that it is well known that for Bessemer purposes a pig iron especially free from phosphorus is required, and that all our ordinary ores, which have been deposited about organic nuclei, or are otherwise contaminated by the remains of fishes and other animal matter, are worthless for the manufacture of Bessemer pigs.

This is rather a serious fact for us, inasmuch as our supremacy as iron manufacturers has been mainly dependent upon the fact that wherever we have coal there is iron stone near at hand. But the same geological agencies which have deposited the organic matter of the coal, have contaminated the ironstones with organic phosphates. Our island, in spite of its general mineral wealth, is very poorly supplied with iron ores, that by their deposition among the more ancient rocks or otherwise are free from phosphorus. With the exception of little insignificant patches, we are reduced to a dependence on the Ulverstone district, and the vast development of the Bessemer demand is now rapidly working this out towards exhaustion. As to the Dean Forest hematite ores, it is very truly observed that they have been longer known and longer worked than any deposits of this class of ore in England; nevertheless, the total quantity raised in Dean Forest is under 200,000 tons per annum, while the amount raised in Cumberland and Lancashire exceeds 2,000,000 tons. If the Dean Forest deposits are so important, how is it that these ancient mines produce less than one-tenth of the ore raised in the modern northern mines? The importance of the Dean Forest deposits has, no doubt, been greatly exaggerated, while all that has been published greatly underestimates the vastness of the Spanish deposits, because the whole truth would but tend to engender incredulity.

It is gratifying to find that the ventilation of the prospects of the Bilbao Company has merely had the effect of increasing the rapidity with which the capital has been subscribed, Messrs. Chadwicks, Adamson, Collier & Co., by whom the subscription is issued, pointing out that, of the eight directors of the Bilbao Iron Ore Company, five are directly and largely connected with the manufacture of iron and steel, and know only too well the impossibility of finding in England deposits in the remotest degree approaching the power of giving adequate supplies. Of the remaining three, one is largely engaged in the sale of both English and foreign ores of this description, and another has been many years connected with one of the largest mercantile houses in the kingdom, and possesses an intimate knowledge of the Spanish language and of the value of Spanish ores.

During the past 5 years they have been consulted with regard to the sale of so-called hematite deposits in almost every part of the West of England, but have invariably found, on obtaining independent scientific reports upon them, that either they have been defective in the proportions of metallic iron, or that they existed in such situations as would place them at a great and permanent disadvantage as compared with other sources of mineral supplies. It is only necessary further to state, that Messrs. Lockhart, Tozer & Co., the sale agents of the Bilbao Iron Ore

Company, are enabled to assert that the various analyses of these ores prove beyond doubt that they contain as great a percentage of metallic iron, and fewer objectionable impurities, than the average North County hematites, and that as to price, Spanish ores have been sold this month in Cumberland at 26s. per ton, thus verifying the anticipation in the prospectus, "that the price of these ores must before long approximate more closely to the values of English hematites."

REPORTS OF ENGINEERS' SOCIETIES.

American Society of Civil Engineers.—At the first regular evening meeting, held the 6th u t., papers on "The Use of a Surface Condenser, with Blast Furnace Boilers," and "Well Boring in Connection with Deep Foundations," were read and discussed, and an apparatus, operated by hydraulic pressure, used in this city to take soundings along shore, down to bed rock or solid earth, was described; other important matters were also brought before the Society.

At the last meeting of the Society of Practical Engineers, an interesting paper was read by the President, James A. Whitney, on the different methods of Pneumatic propulsion.

Traction Engines.—At a recent meeting of the engineers of the branch association of Pomerania, at Stettin, Herr Topffer said that the 20-horse Fowler road engines, which during the late war had rendered great service, had returned to Cologne in a sound and good condition. During the seven months in which they were principally employed in completing the links between those lines of railway that had escaped destruction, they had dragged locomotives and tenders over hills and damaged roads, besides conveying heavy cannon and performing other transport services.

Professor R. R. Werner says that the Allen steam engine, with Porter's regulator, is much admired on account of its rapid and quiet action. A description of it was given, and it was favorably spoken of on the occasion of one of the meetings of the Magdeburg Association of Engineers. The theory of Porter's Regulator is discussed by W. Eckerth; and J. F. Radinger, in a treatise on steam engines with rapid stroke, illustrates the principle which underlies Allen's construction. "Zeitschrift," vol. vii. to vol. xv., illustrated.—G. Grillo describes his paper-cutting and shaping machine. He says that most of the machines at present in use cut perpendicularly, although the oblique cut is preferable in most instances. The worst feature of these machines, however, is that by cutting into the supports, the knives blunt quickly, thereby necessitating a constant grinding and re-setting. In his machine the knife only goes just through the paper parcel. Gadd & Moore's ribbon loom, and Willan & Mill's (Walmsley's patent) automatic shearing machine are favorably noticed. Hemp is specially recommended for stuffing-boxes. A manufacturer at Emmendingen (Baden), prepares the Rhenish hemp in ropes of ½ to 2 in. thick, and of as much as 300 ft. long.

At a recent meeting of the Midland Institute of Mining Engineers the following paper was read by Mr. H. Ogden :

On Exhaustion as a Power for Underground Purposes.—It is with considerable diffidence that I submit this paper to the members of this institute; but seeing that one of the objects of such meetings is to mention our experience in mining matters, and be willing to give as well as receive instruction—this must be my excuse for bringing this matter before you. Its importance or otherwise I leave entirely in your hands.

I have long been convinced that working engines by exhaustion, for underground purposes, is more profitable than by compression. My reasons for thinking so I will lay before you.

More than 20 years ago, at the Low Side Colliery, in Oldham, there were 4 engines working in the pit, being actuated, *i. e.*, motion given them, by one exhausted cylinder at the surface. Of course, the exhausting cylinder is nothing more than the compressing cylinder reversed—which, in the case referred to, was about 2 ft. 6 in. in diameter, and a stroke of, say, 5 ft. ; it was fixed vertically, and worked by a beam from the connecting-rod end of a beam engine, about 20-horse power, which engine also drove the circular saws, a lathe, etc., for the requirements of the colliery. The exhausting cylinder gave motion to 4 vacuum engines at the pit bottom, 2 of which were placed a considerable distance in the workings, being coupled oscillating engines, 12½ in. diameter in cylinders ; the others were single engines, and fixed at suitable parts of the mine for doing the haulage work of the mine generally.

My father had an engine works at the time, and made 2 of the vacuum engines. I, myself, erected one, and attended to the repairs of the colliery. I had opportunities of seeing the workings for a few years, and I can assure the members of this Institute that the engines worked extremely well. Scarcely any heat was set up, save at the two delivering valves at the exhausting cylinder which continually worked a little warm ; neither were we ever plagued with ice. I may add, that the two coupled oscillating engines worked a very long jigbrow at first motion, which would be an inclination of about 1 in 4. The jigbrow was worked intermittingly, while the other 2 engines worked continuously.

I have noticed when there has been a heavy load drawing up the jigbrow, and all engines working at once, they did not go quite so fast, but still worked at a reasonable speed. These vacuum engines resemble steam engines, save that the slide valve is exposed to the atmosphere—consequently the drawing pipes are attached to what would be the exhaust pipe of a steam or compressed air engine ; and the size of the cylinder of the vacuum engine can be arranged for the work you wish it to perform ; *i. e.*, the motion parts of the vacuum engine do not require to be as strong, proportionately to the size of the cylinder, as they require to be for a steam engine. Let us consider what is the effect on the air, by contrasting the two systems, exhaustion *versus* compression. Mr. Warburton, in his paper, very ably describes the amount of heat set up by compression, and lost at the compressing cylinder, and it requires to be kept in remembrance that this loss takes place before your compressed air has rendered you any service whatsoever, or is in a position to do so, and when used sometimes requires heat at the exhaust to prevent the formation of ice.

On the other hand, the effect with exhaustion is a great contrast; for the vacuum engines below are using the air at once, as fast as exhausted, and the engines are working cold, while the air delivered by the exhausting cylinder is warm, certainly, but nothing like the heat expended in the act of compressing the air; while the little heat contained in the air delivered at the exhausting valves, may be accounted for by its quick passage through, and friction in, the pipes connecting the vacuum engines below with the exhaust engines above; therefore a reverse action takes place, though, in exhaustion, heat is so small as to be easily accounted for. I gather, in my experience of exhaustion, that a transmittable power is produced for long distances, the most economical for mining purposes, being in ratio instantaneous; and consider, besides, that, for mining purposes, as is the depth of the mine so is the increased proportional or differential density of the air, which is all in its favor; and the denser the atoms are, in consequence of its weight and attraction, the easier it is to keep up a good workable vacuum. I certainly look upon exhausting engines as being a sound power, and one that requires the least attention of any that I know of. I am not aware that anything of this description has been practically carried out in this district or any other, except at the place and time named. If any of the members have used the principle, perhaps in discussion they will throw more light on the subject. I do not by any means assert that it is noi understood, or claim it as my own invention; and it may seem to some to be a resuscitation of a useless principle; but from what I gathered from it in early youth, and the little that has yet been done with compression as a substitute, I consider it the most useful. Allow me to add that if I was using my own means for underground purposes, I should adopt the system by first having my fixed engines, which should be two coupled for exhausting purposes, at the surface, then my fixed vacuum engines, at the bottom, and a number of light removable vacuum engines, that could be fastened and used directly in any part of the mine.

IRON AND STEEL NOTES.

AMERICAN RUSSIA SHEET IRON.—A writer thus describes in a letter to the "Iron World and Manufacturer" the process of making polished sheet iron at McKee's Port, Pennsylvania: For ordinary sheet iron, the pig iron after puddling is converted into bars 5 in. wide, and is then cut into lengths of 28 in. and from $\frac{3}{8}$ to $\frac{5}{8}$ of an in. in thickness. These are conveyed to the furnaces to be heated for the rolls, on the railway alluded to, and piled up in stacks. But while the furnace men are waiting for the furnace already filled with these piles to come to a white heat, we will get into a safe place and watch the men at the rolls making bars. There are 4 of them to each set of rolls, and they are known by the euphonious names of "hook up," "catcher,' "roller," and "dragout," names which distinctly indicate the office performed by each. Mr. "Dragout" stops at every chance and explains to us the peculiarities and the dangers encountered in rolling. He is a strong-looking fellow and seems to understand more about a rolling mill than simply to drag out bar iron. Every few moments a shower of fiery scintillations shoot out, filling a portion of the mill for an instant with a glow of fiery beauty. In puddling, the impurities in the iron often maintain a mechanical mixture. Under the tremendous pressure of the rolls it is compelled to leave the crevices of the iron in which it lodges, when they are compressed, and it does so in a fiery flood which makes the rollers hop suddenly out of reach. But there is the heater waiting on us to come and see.

The door is raised and a beautiful sight is presented. There, on the inclined surface of the heated coke lies a row of those short bars so white and bright-looking, as to appear like a row of transparent cocoanut candy slabs.

This is the pair furnace, so called because the bars are taken out in pairs to be rolled into sheet iron. It is a small square furnace, and is heated with coal and coke. From 36 to 54 pairs are laid side by side. There are 2 doors, one on the front for coke, one on the side for coal. The use of coal and coke generates a more intense heat than either separately, and the flame of the coal causes the heat of the coke to escape in a current more rapidly. The sides of the furnace are firmly secured by iron castings riveted and rodded together.

Another use of coal flame is to equalize the heat in the furnace, and thus prevent the gluing together of the plates which are subject to the action of the intense heat, and also to prevent the burning of the lower edges of the plates. From 20 to 25 min. are sufficient to heat them, and they are then ready for the rolls.

The heater turns a pair of them on his paddle the same way our great grandmother used to fill their ovens with bread. They are then drawn out and dragged to the rolls, spitting fire as they go.

The rolls are a curiosity; they are large solid cylindrical masses of iron, with a smooth surface, or grooved when desired, and for sheet iron manufacture are "chilled" to secure a hard smooth surface. "Chilling" is effected by pouring molten metal in iron vessels of the shape the roll is desired to be. The contact of the coal metal causes the more rapid abstraction of heat from the molten metal in contact with it, and hence it solidifies more rapidly than the inner portion, is more granular, tough and smooth. It is cast also with a slight arc, so that when the middle part of the surface of the roll is heated more than the outer edges, the expansion will fill up this arc to a straight line, and this makes the sheet iron of uniform thickness.

The thickness of the sheet iron is determined by the space between the rolls, and it is increased or diminished by means of a spanner wheel, which rests on a cog and pinions, elevating or lowering the upper roll. A dial plate attached to the wheel indicates the variations with the utmost precision.

The pieces are taken one at a time and sent under the roll sideways. The second follows immediately, and as they come, the catcher on the other side receives them and passes them as rapidly back over the top of the upper roll to the roller, who again passes them through until they are lengthened the necessary extent. The "spannerman" during this operation turns the wheel which lessens the space between the rolls. The wheel is 6 or 7 ft in diameter, in order to give purchase enough to move the rolls easily.

When the plates are thin enough, he calls "double," and the roller then doubles the plates and passes them through. The upper plate is then lifted and a handful of coal dust is thrown in between, the object of which is to prevent the sheets from sticking together when passed between the rolls. The first process consists in "breaking down," in mill parlance, the plates in which they are made, 5 ft. long. Each third pair of plates are pressed about a foot shorter, and 1 of each is then placed between the other two pairs. This is called "mating," and each three are then called a "pack." These "packs" are then placed one by one in the heating furnace and re-heated to a red heat in about 2 minutes, and then returned and passed a number of times through the rolls, until they are 8 ft. long, in which operation the middle sheet comes out as long as the others.

If 4 or 5 sheets were run together instead of 3, the intense heat the inner ones would receive would cause them to adhere, and they could not receive the equal pressure of the rolls. In finishing, the upper roll is loosened from its couplings, and is permitted to rest its weight on the lower roll. The lower roll is driven by the engine, and the upper by the friction caused by its weight. The friction generates heat, which is carried off by a stream of water poured on the rolls after every third pair has been run. This is done to avoid the effects of the expansion of the rolls in the centre by heat, which, if permitted to take place, would make the sheet of uneven thickness, and even cut it in the centre.

After this, the sheets are placed on a car, and taken to the trimming room, where they are placed 6 in a pack, and the rough edges are sheared off by being made to come in contact with 2 smooth wheels, whose circumferences touch at one point.

They are then packed in large fire-proof air-tight annealing chests, 32 in. thick, and moved by machinery into the annealing ovens, where they are heated for 24 hours, and then permitted to gradually cool 24 hours, after which the sheet iron is ready for market.

The manufacture of the Russia sheet is not essentially different. After "breaking down," the sheets are removed to the washing room, where they are subjected to the action of certain acids, the object of which is to impart, after rolling, that bright glossy appearance which belongs to Russia sheet. The carbon is reduced in oil, because any other material would cause the iron to burn red before removing the sediment. No coal dust is used, as the carbon prevents any sticking. The polished surface is produced by friction in rolling. In "breaking down," the sheets are made 3½ ft. long, and in finishing they are increased to 5 ft.

Two large water tanks, 12 ft. in diameter by 8 ft. in height, supply the mill with water pumped from the river.

This is a model mill, and everything in and about it is indicative of clock-like precision and regularity. The firm are pressed with work, and their reputation as manufacturers of a superior quality of sheet iron has extended over the country. Its superiority is not any longer a matter of opinion, but a demonstrated fact. These works are a credit to Pittsburgh industries, and stand in the front ranks in sheet-iron manufacture. During the past 3 months, orders from every part of the country have been obliged to wait their turn because of the extraordinary demand; but at the present time they are about caught up, and are ready to supply all orders on short notice. Dealers and consumers generally would find it to their advantage to test the value of this sheet iron.

Devotion to the system of protection of which this industry is the product, commands us to look to home sources for supply.

The above firm are about erecting a $30,000 forge for the manufacture of charcoal blooms for sheet iron. Their facilities in the coming season will be such as to enable them to meet almost any demand which may be made upon them. This is saying a great deal, but it is in accordance with facts. American sheet iron, such as is made in their works, must take the first rank in the American market and the manufacturers of it are resolved that in quality and cheapness it shall be excelled by none, home or foreign. Tests of it fully establish the claims made for it. We have seen the foreign and home-made used side by side for months, and in appearance the home product is superior. It is brighter and smoother after long use. It is safe to assert that American skill will, when it obtains the control of this trade, improve upon the present process for manufacture, and invent new processes by which a still better article can be placed in the market at even lower than present prices. We assert this because in all other industries this is the tendency. We would rather rely upon American skill to cheapen a product than on foreign skill. But foreign cheapness does not benefit us in this case, because it is controlled by importers who put the price at the highest notch possible, regardless of its cost. The specialty of the above firm is Russian sheet, but the ordinary brand is manufactured to meet the market demand. We direct attention of users of sheet iron everywhere to the above establishment, and advise them to test its ability to supply a cheap and superior quality of sheet iron.

Iron Interest—Its Progress and Obstacles.—The close of the year has not, in some respects, made as satisfactory showing for the iron interest as the bright prospects of its opening had given us reason to hope, but it is gratifying to know that this is easily accounted for, and the causes are such as to more fully assure us in our former estimate of the greatness and importance of this industry. Whilst we have not been as yet benefited by many of the results hoped for, it is now certain that the practical results will soon be reaped.

The most important branch of the iron interest is the blast furnaces, and it is to these we now refer. Their number has not been increased during the year, and the production of the stone coal furnaces is but little in excess of 1870. This is owing chiefly to the want of an adequate supply of fuel, and so far there is only one reliable channel of supply of the suitable quality. The inadequate demands of the market for the producing capacity of the furnaces, and, therefore, the excess of production, have caused lower prices here than in any other market, without any reduction whatever in the cost of production. Consequently, all the various manufacturing interests have prospered at the expense of the furnaces, and such is likely to be the case until the number and variety of the manufactures increase; but, notwithstanding this there is reason to hope that the next year will bring to the furnaces some important aid. Some of the railroads which are about finished, and others which are being constructed, will open at least three additional coal sources, which will at once cheapen this very important item. One of these roads is of the 3 ft gauge, to run from opposite Carondelet through the Chester and Big Muddy coal fields. This will place these mines very near, and enable the furnaces to receive even the Big Muddy coal at a greatly reduced price. But the Chester coal is certain to become a competing coal for furnace use, and with a 3-ft. gauge road and the road leading from these mines to the river, it will have considerable advantage in transportation, and can be put down at Carondelet at almost the price of our ordinary coal. The south-eastern road also runs through large fields of fine coal suitable for smelting purposes, and this road is also turning its attention to the development of the coal interests. There is also a proposed branch through the Columbia coal fields, which lie nearer Carondelet than any coal yet found, and so far as opened, give a product of most excellent quality. With all of these sources, the prospect of a larger and cheaper supply of fuel is certainly quite flattering.

The coke works, which were organized more than a year ago, have not yet gotten into successful operation, but have demonstrated enough to render it certain that a good quality of coke can be made from our common coals by grinding and washing the coal before coking, and it cannot now be long before the process will be in successful operation. When these several conditions are fulfilled our supremacy as an iron market is established. But the production of cheap iron here is not entirely dependent upon cheap fuel. The cost of transportation is too great and the delays in transfer very harassing; for instance, the Iron Mountain Railroad Company charge $8 per car of iron from Carondelet to St. Louis (a distance of 6 miles), although the iron is both loaded and unloaded without cost to the railroad, and cars are sometimes as long as 7 days coming this distance. Such an expense and delay in making deliveries when the haul is only 6 miles cannot be sustained upon any principle of reciprocal interest, and demands the enlightened attention of the managers of the Iron Mountain railroad. Next to this is the delay and cost of transfer. In many cases cars loaded with fuel have been detained 5 weeks at East St. Louis when the furnaces were needing it, and still longer delays in making shipments of metal by transfer from the furnaces to East St. Louis were experienced. With the furnaces at Carondelet in full blast they handle 1,300 tons of ore, fuel, metal, and rails per day; but so far the railroad appliances for handling this large business seem unnecessarily crude. These difficulties have suggested a road from East St. Louis to Carondelet to be built as a toll road for the use of all roads, and will be a great assistance to an interest now suffering so much from the hindrance indicated. This road will be only about 7 miles in length and should be built in the next 60 days, as there is but little grading to be done. The Missouri Pacific propose also to put in a branch to Carondelet. This will give the furnaces the advantage of competing ores and greater varieties of mixtures. With the various roads that are now proposing to build to Carondelet, a bridge is also necessary, and a charter and organization are completed, and it will likely be well under way before the close of 1872. When these improvements are consummated furnaces will be out of the woods; until then the tariff they pay at home will more than counterbalance the protection that their congressional champion, Mr. Kelley, can possibly get.

With a confident belief that all these hindrances are soon to be removed, we shall leave the furnaces to see how the other iron interests have prospered. With them it is not difficult to guess the result, as with a cheaper and better qualitied iron than could be had anywhere else, they have been unusually successful, and they should be encouraged in such degree as to induce a large increase in the erection of manufactories in the various departments. All of them have run to their full capacity, and some have turned out more work than ever before, and are even finding a large market for their goods on the Pacific coast and in the North and East, when they have heretofore been supplied entirely from the Eastern markets. The Rail Fastening Company, which started in 1871, has been unusually successful, and intend making large additions to their works. The wire works have also been prosperous, and these will be largely increased during the coming year. The Vulcan Works made a very successful start with their new mills. At the first effort, the machinery turned as easily as if it had been in use for years, and produced a remarkably handsome rail of excellent quality. These works are a credit to the energy and enterprise of the builders, and to be in the centre of a country where so many railroads are being built and to be built, it is gratifying to know that we have a mill capable of turning out every day rails for 1½ miles of road. This is certainly a large capacity, but, taking account of the roads west of the Mississippi river that are already built, being built, and projected, and it is plain that we are in want of several such establishments.

Of all the manufacturing interests that would do well here, large steel works, both for merchant steel and steel railroad bars, seem to promise best, as it is now practically demonstrated that Missouri iron is well adapted to steel purposes. This is proven in that several hundred tons of it have been tried at the Bessemer steel works at Troy, N. Y., and first-class steel rails made from it with entire satisfaction. The iron that can be used for this is difficult to obtain in this country, and in Europe commands a much higher price than the ordinary pig iron. Here, where it sells at $5 per ton less than the common irons of Pennsylvania and New York, seems to us the place for such works, and with the market in this condition, with the furnaces running at ½ their capacity, with sales during the year of say, 25,000 tons to go up the Ohio river, it certainly looks as if large steel works could be erected here with good margins for profit, in the centre of a country where there will soon be no limits to its capacity and demands. Before there was a furnace in this State, before the Iron Mountain Railroad was built, before the Iron mountain had its sides disturbed by the pick and torn by the blast, a metallurgist of some note predicted that the Mississippi valley would become the great iron manufacturing centre of America. His prediction is gaining strength with each succeeding year, and in less time than many imagine the proof of it will be visible.

Last year the production of all the furnaces was: of stone coal furnaces, 36,200 tons, of charcoal furnaces, 33,303; total, 69,503 tons. This year we are unable to get full statistics in time, but estimate it as slightly larger. The low prices of pig iron for the first 8 months of the year was a dam-per on production, rating, as it did, at about $31 per ton, but for 4 months prices have ranged from $38 to $39, and better prospects are ahead. The following are the statistics of the products, etc., of such furnaces and mills as we have obtained:

Stone Coal Furnaces.—Germania Iron Works, Carondelet, opened May 1st, produced 850 tons pig iron, and 75 tons bloom.

Lewis Iron Company, two furnaces; productions 1871, 13,500 tons pig iron; 1870, 6,000 tons.

South St. Louis Iron Company; production 1871, 10,300—a balance of 3,000 tons is on hand awaiting shipment, mostly to points on the Ohio river.

Vulcan (and Kingsland) Iron Works. This mill was idle several months, owing to low prices of iron, "induced by reduction of tariff." We have therefore only obtained their capacity, etc.: Capital of company, $2,000,000; number of hands employed, 800; capacity of furnaces per year, 30,600 tons; capacity of rail mill per year; 40,000 tons; wages paid per month about $40,000.

Charcoal Furnaces.—Irondale furnace, February 1 to October 13, 1871, hot blast, 4,909 tons; December 1 to December 31, cold blast, 322 tons; mainly sold in Pittsburgh.

Pilot Knob Iron Company. Production of 1871, pig iron, 6,275 tons, of which 1,520 tons were sold to Pittsburgh, and 2,670 tons to Wheeling; the remainder here

Iron Mountain Company.—The following will give the operations of the Iron Mountain Company for 1871:

Iron ore raised and shipped from the mountain: ore raised, 169,796 tons; ore shipped, 156,310 tons; ore delivered to furnaces at Carondelet, 56,571¼ tons; ore shipped by river to Ohio and Grand Tower, 92,530 tons; ore shipped by rail, 35,951 tons; pig iron produced, 6,759 tons.

Pig iron shipped by river, 6,014 tons; by rail, 1,410 tons; disposed of in the city, 4,000 tons.

Of the above ore shipments by rail, 19,389 tons went to Indiana; 900 tons went to Chattanooga.

Balance shipments by rail went to Pittsburgh, Cincinnati, Wheeling, and other points.

Iron ore on landing January 1, 1860, 100,000 tons; January 1, 1871, 80,000 tons.

The Scotia Iron Company was not in operation the entire year, but made 5,525 tons, of which 2,000 tons were of cold blast. The sales have generally been made in St. Louis.

The Helmbacher Forge and Rolling Mills (stone coal) commenced operations about the last of 1870, and its productions have been as follows:

	Tons.
Bar iron produced	2,120
Railroad car axles 11,300 or	1,650
Sundry forgings	150
Total production	3,920
Pig metal consumed	2,300
Scrap iron	2,350
Coal	15,000
Men employed	180
Wages paid during the year	$101,500

The largest shaft ever made in the West, was made in November by A. Helmbacher, 20 ft. in length and weighing 13,000 lbs.—*St. Louis Times.*

RAILWAY NOTES.

Speed of Passenger Trains in England.—From a London contemporary we get the statement below of the speed of those lines which make the best time in that country. On this side of the Atlantic many exaggerated notions prevail with regard to the velocity with which trains sometimes move; but cautious persons will admit that some of the lines go quite fast enough:

"What speed are we going at?" is a question one often hears asked in railway carriages, and it might very easily be answered correctly. Most people, however, have a general sort of impression that express trains always travel at the rate of 60 miles per hour, and when late and making up time very much faster. But let us see what the speed of some of our fastest trains really is. The Limited and Irish mails run from Euston to Rugby, 82½ miles, in 2 hours, or at rather less than 42 miles per hour. From Croydon to Brighton is done at under 43 miles per hour, and the speed of the West of England express from Waterloo Bridge is about the same. The continental trains from Charing Cross and Cannon street to Dover also do about 43 miles an hour. Two trains, however, are rather faster. The Manchester express goes from Kentish town to Leicester, a distance of 97½ miles in 2 hours and 8 min., the speed being 46 miles an hour; and the Scotch express from King's Cross at 8.10 reaches Peterboro', 76½ miles in 1 hour 37 min., travelling at over 47 miles an hour. Of course, in such long runs the velocity will vary considerably, as the train ascends or descends inclines, or is passing stations and junctions where high speed would be dangerous. A few miles may be done at 60 or 70 miles an hour, and some at 20 or 30, but the average speed is usually about 45.

However, it is very easy to test these statements experimentally. Most people have watches with seconds hands, and every railway has a post at every ¼ mile. Now 900 divided by the number of seconds which elapse between the moments of passing any two posts of ¼ mile apart will give the speed of the train in miles per hour.—*American Railway Times.*

Curved Smoke-stack.—The "Boston Transcript" says, for the benefit of railroad travelers, that the desideratum so long sought for by inventors, namely, a practical spark and dust arrester, after repeated experiments and failures, has at last been brought to what may be termed perfection by a gentleman of Massachusetts. The invention is simply a curved smoke stack, in nearly the shape of a "horn of plenty," attached as ordinary smoke stacks are, the mouth running backward toward the centre of the locomotive. Within, near the enlargement at the upper curve, is placed a wire screen at an angle of about 45 deg. with the direction of the smoke, and the usual screen is placed over the immediate outlet.

Just below the first screen a perforated steam stack is run horizontally through the smoke stack connected with the boiler by a valve-pipe under the control of the engine-driver. As the refuse matter from the furnace passes through the stack, it is moistened by the fine spray ejected from the perforations, thus deadening the particles and increasing their weight. Striking at the inclined angle named above against the first screen, they are prevented from passing through, and fall to the under curve of the stack, whence, through the natural motion of the engine, they are directed by a tube to beneath the boiler, and thrown upon the track in a moist and consequently harmless state.

This invention has been on trial upon the Fitchburg railroad during the past three weeks with sufficient success to warrant the inventor in pushing his plans to perfection. The advantage of the curved stack is not only in the prevention of dust and cinders upon the train, but to avoid the damage by fires along the track, which have been the cause of so much expense to railway companies. This latter object is completely attained, and that without any apparent loss of power. It was at first supposed that the draft would be so seriously checked by the new stack as to counterbalance the other advantages, but experiments have shown that such is not the case, and that steam is made equally as well as with the ordinary stack.

Condition of the Pacific Railways.—The Secretary of the Interior, in his annual report, gives the following interesting exhibit of the affairs of the three Pacific railways :

UNION PACIFIC.

Subscriptions to capital stock	$36,783,000
Subscriptions paid in	36,672,300
Receipts of all kinds	7,362,015
Cost of road, including fixtures......	112,793,618
Total indebtedness..................	74,653,512
Due the United States...............	27,236,612

CENTRAL PACIFIC.

Subscriptions to capital stock.......	$59,644,000
Subscriptions paid up	54,283,190
Receipts	7,326.327
Expenses	3,745.766
Net earnings	3,580,560
Total indebtedness..................	71,430,732
Due to the United States	27,851,000

NORTHERN PACIFIC.

Stock subscribed	$100,000,000
Stock paid up	2,241,600
Expenses to June 30, 1871	4,936,871
Indebtedness	9,085,764

—*Railway Register.*

A Novel Method of Operating a Railroad by Telegraph.—The Denver (Col.) Correspondent of the "New York Tribune," in a recent communication, gives the following interesting details of a novel method adopted for running of trains on the Denver and Rio Grande Railroad by telegraph :

"It is hoped that accidents by the narrow gauge will be few, because with the ordinary brake a train can be brought to a stand as quickly as other trains can be by the improved patent brakes. The centre of gravity in the small cars is 10 per cent. lower than in the larger ones, hence the cars are least likely to overturn, and the whole weight of the train being less, collisions must be less violent. The Denver and Rio Grande line is conducted under a new method. The engineer alone has charge of running the train. The conductor is an agent, and he is also a telegraphic operator. He carries a telegraphic apparatus with him, and stations are attached to telegraph poles —being little more than shelves—and the agent communicates orders to the engineer. The poles are numbered in mile sections, from 1 to 26, and the miles are marked on the poles as if milestones. By this means the engineer, who keeps record of the condiiton of the track, can report to the master mechanic at the end of the trip, or sooner, any defect within 100 ft., by naming the number of the pole and section where work is needed. The master mechanic has charge of maintenance of way, and, having reports by telegraph, as above stated, he at once directs where work is to be done. It is reported that this road is to be extended to the old city of Mexico, and that offers of money have been made from the owners of rich mines in that remote region. Thus we may expect that this road, now just commenced, will be extended to the capital of the Montezumas—a distance of over 1,800 miles from Denver. It is to be said, in addition, that an extension of the narrow gauge northward has been surveyed, running through our town, to connect with the Union Pacific at Pine Bluff."—*The Telegrapher.*

Railroad Bridge at St. Joseph, Mo.—About 200 men are now employed on this bridge. The caisson near the western shore is being sunk, the work is going on night and day without intermission.

The Goodale Steam Brake Company are putting their brakes upon the trains of the Ohio and Mississippi and Iron Mountain railroads. These roads have investigated the matter thoroughly, and have decided that the Goodale patent possesses many points of superiority over any other.

Atlantic and Pacific.—Arrangements have been completed for ironing and equipping an important branch of this road, running from Pierce City west hrough Carthage, Jasper county, into Kansas.

The St. Louis, Lawrence and Denver.—It is announced that this road, running from Pleasant Hill, on the Missouri Pacific, to Lawrence, on the Kansas Pacific, will be completed about the 15th inst.

ENGINEERING STRUCTURES.

Kansas City Bridge.*—Civil engineers, bridge builders, and all persons connected with public works, are under great obligations to the authors of this valuable monograph upon the first bridge constructed across the Missouri river, for the admirably complete and clear manner in which they have described the various processes conducted by them. Their modesty has prevented their taking that credit to themselves which is their just due. The difficulties which presented themselves were overcome one by one as they occurred, in such a quiet and successful manner, that very few persons who had not watched the progress of the work could believe that there were any unusual difficulties. One who has had good opportunities of knowing and who has seen a few other bridges built, believes that the readers of Van Nostrand's Magazine will be interested by a brief comparison of the processes used at Kansas

* Kansas City Bridge. By O. Chanute, Chief Engineer, and G. Morrison, Assistant Engineer. New York: D. Van Nostrand, 1870.

City, in sinking deep foundations, with those used and now in use at other places.

The system of sinking cylinders by means of compressed air, through water and semi-fluid strata, was first practised about thirty years ago by French engineers, to get at some coal mines under the bed of the Loire. The air-lock was there invented, and successfully used.

The process was then applied to bridge foundations by sinking two or more tubes to form a pier.

It was soon discovered that there were three objections to this plan.

The first was, that all the material to be raised had to pass through the air-lock. This was a very slow and expensive process. The second objection was, that owing to the small area of the foundation of the tubes, as compared with its height, it was difficult to keep it truly vertical, and still more difficult to replace it, if it once tilted out of position. The third was, that if the soft materials around the tube should be scoured away, it would not be self-supporting, unless sunk into the rock itself.

Two important modifications of the process were introduced almost simultaneously by Mr. Brunel, in his foundation 82 ft. below water at Saltash, and by M. Fleur Saint-Denis, at the bridge between Strasbourg and Kehl, over the Rhine, whose foundations are about 65 ft. deep.

Mr. Brunel used a single tube 35 ft in diameter, instead of several small ones. M. Saint-Denis used 4 caissons firmly bolted together into one before sinking, so as to form a caisson the whole size of his intended pier. This gave sufficient base to insure stability in sinking, and made the pier self-sustaining in case of the sand being scoured away.

This principle of *concentration*, as distinguished from the other plan of separate tubes, was adopted by Mr. Chanute at his bridge, before the success of the St. Louis and Brooklyn foundations had settled the question in its favor. Several eminent engineers had thrown the weight of their professional authority in favor of the tubular plan, and several important bridges had been constructed in that form in this country, although at a great expenditure of time and money.

Mr. Chanute was able to put down his foundations without the use of compressed air, although, in his deepest pier at least, he was prepared to use it if necessary.

The objections to the use of compressed air in tubes were overcome in the system invented by Brunel and Saint-Denis, and since so successfully used at St. Louis and Brooklyn, by the use of the water-shaft.

Brunel confined his compressed air to a chamber in the bottom of his large tube, which communicated with the external air by a pneumatic tube surrounded by an open tube full of water, and fixed to it by radial partitions. The air was forced into the chamber, and the workmen gained access to it through the pneumatic tube, while the materials to be excavated were raised through the outer water tube by buckets and windlass.

At the Kehl bridge, the whole caisson, or rather 4 caissons, formed a compressed air chamber, reached by eight pneumatic tubes, and 4 large water-shafts, used for the same purposes as at Saltash. But in the water-shafts were placed 4 powerful elevator dredges, which raised the materials through them without cessation.

Although this plan has been followed by continental engineers ever since, most English engineers have stuck to the old-fashioned plan of raising all the materials through the air-locks in bags. This tedious process has been followed in the bridge at Omaha, and accounts in a great measure for the length of time which it has taken to build it.

The question as to whether it is proper to use compressed air, or to dredge through open shafts, is one to be determined by the nature of the material to be excavated. In sand rivers, where the dredges feed themselves readily, and there are few sunken logs or *debris* to pass through, the system of dredging is as rapid as manual excavation in compressed air, and much less expensive. But if the material is hard, an air chamber must be used, so that men can attack the river bed with pick and shovel.

Mr. Chanute decided in favor of the dredges, and experience proved the accuracy of his judgment. A pier 70×20 was sunk through 12 ft. of water, and $34\frac{1}{2}$ ft. of sand, to the rock, in 64 days; the time actually employed in dredging and raising being about 600 hours.

The E. pier of the St. Louis bridge was sunk through 40 ft. of water and 63 ft. of sand, to the bed rock in 126 days; but the area to be excavated was four times as great as that of Kansas City Bridge No. 4.

Besides the deep foundations of No. 4, there were others not so deep, but all difficult on account of the rapidity of the current, and the difficulty of maintaining false works.

These piers were put down in different ways, all successfully, and in modes showing great adaptive skill on the part of the engineers.

Old Indians, when they give their boys a gun for the first time, tell them that it is a wicked Manitou, and will kill them if they give it a chance.

This is the only safe rule to be adopted in dealing with one of these large rivers. Never trust it; never give it a chance to hurt you; always expect that it will do the thing you do not want it to do, and then you will finally overcome it.

T. C. C.

The St. Gothard Tunnel.—Another Grand Engineering Work.—The pass of St. Gothard was the most frequented of all the routes across the Alps until the commencement of the present century; but, as it was not practicable for vehicles, it was gradually deserted after the construction by Napoleon I., of the road over the Simplon. The lose of the traffic induced the cantons through which the route passed to construct a carriage road quite as good as that on the Simplon. The work was commenced in 1820, and finished in 1832, and it is one of the greatest monuments of engineering skill to be found in Europe. In magnificence of scenery the St. Gothard is superior to all of the passes, unless we except the Stelvio. To the mere pleasure seeker, it will, therefore, be a matter of regret to see this superb road deserted for a hole through the mountain Ever since the Mont Cenis tunnel was projected, the Swiss and Germans have felt that a large share of traffic would be diverted to France. For military and strategic reasons, it was, also, felt that equally good facilities ought to be provided on the other side of Switzerland, and all of the necessary surveys were made many years since; but the jealousy of the French, and the fear of that nation, has prevented the commencement of the work. The moment, however, that France was powerless to prevent, the project was revived, and we now hear that a contract for the construction of the tunnel has been concluded between the Swiss government and a syndicate of German bankers under the protection of the imperial government of Germany. The work will be about twice as long as the Mont Cenis tunnel, and it will be considerably more difficult, as it must pass under several rivers and lakes, and encounter the hardest rocks of the Alps. The summit of the present carriage road is 6,507 ft., but the railroad will pass under peaks varying from 8,750 to 10,900 ft. There is no distinct peak of St. Gothard, but an extensive ridge of elevated ground which bears that name.

Geologists will be greatly interested in the work, as this part of Switzerland abounds in a large variety of choice minerals, and some important questions may be solved by the projected work. The total cost is estimated at $37,000,000. Of this amount the company will raise $20.000,000, leaving the balance to be raised by assessment upon the cantons and countries immediately interested in the project. There is a general belief among engineers that the work will cost much more money than the above estimate, but, as rich governments stand as security, there seems to be little doubt that the undertaking will be pushed to final completion. The new road will bring Germany and Italy into closer political union, and, in the event of war, give these powers a decided military advantage; but this feature of the undertaking is of small importance in comparison with the enormous traffic that will flow through the tunnel between the nations of the north and the remote inhabitants of Asia. Its principal utility will consist in facilitating trade and travel between Europe and Asia, by way of Italy. The extreme eastern points within its circle of traffic will touch the outstretched hand of our Pacific Railroad, and the commerce of the whole world will be benefited by the completion of the gigantic scheme. It is not many years since the river Danube was the highway for the commerce of the world. The boats moored at the bridge of Ratisbon, far up in the interior of the Continent, were manned by sailors who were the boast of that period, when suddenly, by the discovery of the passage around the Cape of Good Hope, commerce was diverted to new routes, and we have nothing but the ancient bridge and the quaint old storehouses to tell us of the magnificence of the past. The completion of such works as the Suez Canal and the tunnels through the Alps are great illustrations of the triumph of science over all obstacles.

The trade, which, for a time, was diverted to new routes, appears likely to return to its former channels. The Austrian government already have a railroad over the lower Alps, connecting with Trieste and Venice, so that they will profit by the revival of trade in this direction.

It is difficult to anticipate how long it will require to complete the St. Gothard tunnel, but with improved machinery and aided by the experience of Mont Cenis, it can hardly endure twice as long as the last famous undertaking. It is a bold enterprise, well worthy of the age in which we live. —*Iron World and Manufacturer.*

THE ROCK ISLAND BRIDGE.—The Rock Island bridge superstructurists are still devoting their best energies to the construction of the draw, which is one of the heaviest ever put up in the country, being 366 ft long, or 60 ft. longer than the side of a full block in the city. Its construction requires 750 tons of iron, besides the wood work. This vast weight will swing upon a massive turn-table, operated by an engine located on the railroad level of the bridge. This engine and the necessary machinery are being constructed. In case of an accident to the engine, or if for any other reason it cannot be operated, the draw can be turned by a set of hydraulic ja k-screws, provided for the purpose. Some of the iron sections of the turn-table are of such weight that one of them is a full load for a car. Work upon the third span from the Iowa shore will be commenced in about two weeks. The false-work for the fourth and last span will not in all probability be commenced upon until the river is frozen over at the point.—*Exc a ge.*

ST. JOSEPH'S BRIDGE.—More than 3 000 cubic yards of stone have been delivered on the Kansas shore for this new bridge, and it is arriving at the rate of 13 car-loads daily. Temporary dikes have been constructed on this shore which have turned the lower water channel from it. A permanent dike further down will be half a mile long and will be protected with rip-rap. It is now 550 ft. long and 60 ft. wide. The contractors, the Detroit Bridge and Iron Company, commenced sinking the western pier on the 4th inst. It will reach rock 45 ft. below the surface Col. E. D. Mason, the accomplished engineer who had charge of the construction of the Hannibal Bridge, is supervising the structure.

NEW BRIDGE AT CARONDELET.—It is stated that a large amount of stock has been subscribed, and that the proposed bridge will be commenced early in the coming season. It will be of iron, and adapted for railways, with crossing for wagons, etc. below. Its entire length, including trestle-work, will be 2,174 ft. Its estimated cost is $2,000,000.

LAKE CHAMPLAIN BRIDGE.—The trestle work of the new railroad bridge across Lake Champlain is 1,800 ft. long, and it is intended, at intervals of 100 ft. to build piers, 30 ft. square at the bottom, and 12 ft. by 30 at the top. The boat to be used as a drawbridge is 300 ft. long. 30 wide, and 12 high, contains 250,000 ft. of lumber, weighs about 3(0 tons, and is expected to draw 2 ft. of water. 800 piles, length 80 ft., were required to build the trestle work, from either shore to the draw; this latter is to be connected to a pier by hinges, and swings back and forth like a door, by means of a chain.

BOOK NOTICES.

NOTE-BOOK ON PRACTICAL SOLID OR DESCRIPTIVE GEOMETRY, CONTAINING PROBLEMS WITH HELP FOR SOLUTIONS. By J. H. EDGAR, M. A., and G. S Pritchard. London and New York: Macmillan & Co., 1871.

When our Civil and Military Engineering Examinations are daily making larger demands for geometrical proficiency a new and exceedingly lucid Note-book on Descriptive Geometry comes well-timed. · Though much has been done to expand this collateral offshoot of geometrical science since M. Monge, of the Ecole Polytechnique, first started it, the co-ordinative characteristic of a science has hitherto been wanting; it has contained, doubtlessly, all the abstract principles of orthographic projection, but principles, to be available, must be interdependent and derivative. Messrs. Edgar and Pritchard have felt this deficiency, and have done much to remove it. Their book, unlike the majority of cheap hand-books, is neither "patchy nor scrappy," but a continuous and coherent whole. "Elementary Explanations, Definitions, and Theorems" come first, followed by 28 problems on "the Straight Line and Plane;" to these succeed Solids, first singly, and then in "Groups and Combinations." In like logical order we next have "Solids with the inclinations of the plane of one face, and of one edge or line in that face given," and then "Solids with the inclinations of two adjacent edges given," and, lastly, in this category, "Solids with the inclinations of two adjacent faces given" So far we have the principles of projection in a much more perfectly co-ordinated arrangement than we have hitherto found them in, and we must say that the mere act of mentally assimilating this interdependence of principles would be wholesome discipline, even if it did not, as it unquestionably does, facilitate each successive step in progress, and, most of all, conduce to an integral entertainment of the subject. Again, as naturally derivable from the consideration of the inclined faces of solids, we arrive at "Sections by oblique planes," and "Developments," or the spreading out in one plane of the adjacent faces of such solids; and, finally, the development of curved surfaces. "Miscellaneous Problems" now have place, and amongst them we notice one from the "Science Examinations" of last year. The sequence of the 4 next chapters is judicious. "Tangent Planes," "Intersections of Solids with plane surfaces," "Intersections of Solids with curved surfaces," "Spherical Triangles." A short chapter on Isometric Projection (quite as long as it deserves) ends the work, the authors of which we rejoice to find (in these days of "result-seeking") much more desirous of results actual than results visible, and accordingly, foregoing a somewhat too popular profusion of diagrams, which, while it undoubtedly facilitates the bare apprehension of subject-matter, by no means enforces that comprehension of the subject which attends upon the act of accomplishing a mental diagram for ourselves. In this expression of their conviction the authors, we observe, are at one with Mr. Binns, who, with the same sincerity, and for like reason, resisted the systematic use of models in the teaching of "mechanical drawing."

Messrs. Edgar and Pritchard have produced an inexpensive, but a well-digested, comprehensive, lucid, and typographically attractive *vade mecum*. —*Nature*.

INORGANIC CHEMISTRY. By GEORGE WILSON, M D. Revised and enlarged by H. G. MADAN. London and Edinburgh: W. & R. Chambers. For sale by Van Nostrand.

The earlier edition of this excellent work was widely used in this country, because in addition to an attractive style, the author afforded a means of comparing the two methods of notation in all important formulas. This latter advantage is not retained by the new editor; but the work has lost nothing in clearness of exposition or excellence of method by the revision.

MARVELS OF POND LIFE. By HENRY J. SLACK, F. G. S. London: Groombridge & Sons. For sale by Van Nostrand.

This is a delightful book for amateur microscopists, as it affords instructions in regard to collecting living objects for the microscope every month in the year.

The author is an enthusiastic lover of the study of the lower organisms, and his style is calculated to awaken a desire to work in this department of natural history.

PETIT TRAITE DE PHYSIQUE. Par M. JAMIN. Paris: Gauthier Villars. For sale by Van Nostrand.

This is a convenient hand-book of 700 pages, containing a complete compend of physics. The illustrations are numerous and excellent, and serve to elucidate the most advanced state of experimental science. The widespread celebrity of the author's larger work will guarantee a demand for this later though smaller treatise.

A COMPLETE COURSE OF PROBLEMS IN PRACTICAL PLANE GEOMETRY. By J. W. PALLISER. London: Simpkin & Marshall.

Mr. Palliser is a master and lecturer on geometrical drawing at the Leeds School of Art and Science, and the work is specially designed as a text-book for students in art and science schools and night classes connected with the Science and Art Department. It contains constructive and descriptive problems in plane geometry, to prepare candidates for any of the Government examinations in this subject; and is to be followed by one on "Solid Geometry."

PICTURESQUE ARCHITECTURAL STUDIES. By WILLIAM YOUNG, Architect. Parts 2 and 3. London: Spon.

The title "Picturesque Architectural Studies," scarcely describes the work, which consists, so far as it goes, of designs for lodges, cottages, and so forth, by the author, some of which have been carried out. Mr. Young in the present parts includes plans and elevations for cottage hospitals. A design for a vicarage-house is not without merit. Mr. Young has a free fancy and a freer pencil. The sketchy style of drawing adopted leads to want of precision.

FLINT. A PAPER READ BEFORE THE GEOLOGISTS' ASSOCIATION. By M. H. JOHNSON, F. G. S. Printed for private circulation. Bacon, Printer, Lewes.

This paper was read in June last. It treats of the deposit of flint or silex in chalk, and suggests a theory to explain how sponges, etc., produce the flint nodules in chalk mud. The author proposes to utilize such a process in the arts and manufactures, by coating perishable surfaces with silex while embedded in calcareous or argillaceous mud, with the help of soluble silicates and decomposing organic matters. An engraving is given of a specimen of orbicular silica, the flints having been deposited in concentric circles, the markings of which, curiously resemble the concentric circles on the rocks of Northumberland and Argyleshire, as well as the "spectacle ornament," as it has been called, upon the standing stones in Scotland. Still, we are far from suggesting anything like identity. The concentric circled markings on rocks, on the stones at New Grange, on the Scottish and other stones, are associated with other markings more obviously carved, but the coincidence is curious.

MISCELLANEOUS.

M. Pleischl, of Vienna, claims to have discovered a vitreous enamel for metals which combines the properties of durability, freedom from noxious ingredients, and malleability by contact with the substances to which it is applied, and he has lately exhibited some specimens of enamel work which have elicited high commendation. Among these were plates of copper, the coating of which bore exposure to heat and resisted the action of acids, possessing also the important property of allowing the plate to be bent to an acute angle without either scaling or cracking. This enamel is free from lead or zinc. It is is not liable, therefore, to the serious objection to lead glazes, of contaminating liquids contained in the vessels coated with it with poisonous salts. It also bears very rough treatment, endures a hard scratching with a knife without losing its polish or showing any trace of the implement, and, though heated to any degree, even to redness, it continues to be perfectly sound, the only precaution necessary to be taken being not to cool it suddenly by contact with water. It is harder than glass, which it scratches, and is not even scratched or marred in the slightest degree by the most thorough scouring with sand.

The great bridge at St. Louis is progressing rapidly. The concrete cr foundation for the last pier, a small one on the Illinois side of the river, has been laid and the bridge company will have no further use of the air pumps, voltaic armor, etc. The masonry, of which there will be 103,000 cubic yards, is about two-thirds completed, and the superstructure has already been commenced. The cast-iron plates at the piers have been placed and prepared for the reception of the steel tubes forming the spans. It will be completed in about a year from now.

Lubrication of Steam Engines.—It has been a long time the practice with horologists, to use graphite as a reducer of friction, in even the most delicate pieces of mechanism. In blowing engines also, if the gearing is copper, graphite is the only lubrication used. These facts led M. Thoma, C. E., of Memmingen, to try a mixture of graphite (prepared by decantation) and hog's lard, first in the stuffing box of a pumping engine, and subsequently upon a steam engine. The result was very satisfactory; the only care requisite was to keep up the quantity of graphite in the mixture, as otherwise it it becomes too fluid. The next experiment was made with a paste of graphite and water. The result was equally good; the slight escape of steam into the stuffing box was sufficient to keep the graphite moist, and the lubrication seemed quite perfect, although there was no fatty matter present.—*Railway Times.*

From China to England.—While we can hardly feel the enthusiasm of our contemporary (the San Francisco "Bulletin") in the comments we quote, we still feel that they are in a great degree true, or at the least worthy of notice. It says:

"Our English cousins are further astonished at the rapidity with which we move in this country; and at the fact that a passenger who left this city by the overland railway on the 2d ult., and took passage at New York on the Wisconsin, arrived at Liverpool on the 19th, making the trip in 17 days, they are so surprised that they telegraph it back as an 'unprecedented' occurrence. It would seem that the British public are just wakening to knowledge of the fact that Yankee enterprise has furnished the shortest and most expeditious route between Liverpool and not only San Francisco, but China and Japan, for the time made by this passenger did not beat that which may be made by anybody who leaves this city in time to connect with steamer at New York. In fact, nearly as rapid time has been made by freight from this city to Liverpool. A consignment of raw silk, valued at $68,000 gold, which arrived here per the "American" on July 15th, was started overland on the 17th, arrived at New York on the 27th, less than an hour after was on board an outward bound steamer, and arrived in Liverpool August 7th, making the transit from San Francisco in only 20 days, and from Yokohama in but 46 days, two days delay being occasioned by transfer and passing the custom house at this city.

"When express trains are run as doubtless they will be, to accommodate Liverpool freights overland, the time can be shortened 3 days, making the distance from Yokohama to Liverpool in 43 days, as against 73 days by the English steamers *via* the Suez canal. The result cannot but tell on the commerce of this port, which might be increased immensely, especially if the dock system were reformed so as to reduce to a minimum the expenses of vessels discharging cargoes here."—*Railway Review.*

Steam Boiler Explosions.—The following record of boiler explosions in the United States during 1871, is copied from the Report of the Hartford Boiler Insurance Company.

	Explosions.	Killed.	Wounded.
Saw and planing mills	30	57	46
Steamboats and tugs	22	289	137
Manufactories of various kinds	22	13	19
R. R locomotives	13	21	38
Flour and grist mills	5	15	5
Oil wells	3	3	1
Brass foundries	2	1	3
Rotary bleachers	2	..	..
City Water Works	1	..	..
U. S. Navy Yard	1	.	
Iron Foundry	1	2	3
Miscellaneous	3	3	9
	105	404	261

Experiments to Determine the Gravity of the Earth.—Pendulum experiments for determining the gravity of the earth are about to be made in the Mont Cenis Tunnel by Father Secchi, M. Diamiller-Muller and M. R. P. Deuza. They will be made first in a lateral chamber about the centre of the tunnel, and will be afterwards repeated at the corresponding vertical point on the mountain, the difference of level being about 1,600 metres. In addition to these observations, they propose to determine the earth's magnetism, and the temperature of the strata to which they can obtain access. By preliminary observations, they have ascertained that the movement of the trains will not to any serious extent interfere with the precision of the observations. Telegraphic wires will be laid down for the purpose of chronographic registration, and the observing chamber will be ventilated by special air conduits.—*Comptes Rendus.*

New Filtering Process.—The waterworks of Dunkerque, completed in 1870, include the application of a filtering process, arranged by M. Pauwels, the city engineer, in charge of the works. The filtering system of Dunkerque is analogous to the self-cleaning filters established at Paisley by Mr. Thom, and in which the duty is equal to 27.-500 gals. per 24 hours, with an area of 7,100 sq. ft,

The total thickness of M. Pauwels' filter is only 26 in., arranged as follows :

in.			in.
5 124	Formation	Bricks laid on edge	18.118
1 194	Formation	Tiles set in Portland cement	
5.900	Formation	Calais gravel	
5 900	Formation	Culm	
7.882		Filtering bed of fine sand	7.882
26.000		Total thickness in inches.	26 000

The 5.9 in. of culm in the formation is laid in 3 beds, in which the fragments decrease in size from the bottom to the top. This material has given good results, allowing the water to flow through, and being absolutely impermeable to the grains of sand which form the upper bed. The gravel, on the contrary, allows the sand to pass gradually, gets choked rapidly, and reduces the useful effect of the filter. The duty of the filter reaches the proportion of 8 cube metres to 1 sq. metre per 12 hours.

It is well known that in a certain number of localities the results of filtration have not been entirely satisfactory. M. Pauwels believes that he has overcome all difficulties by the combination he has adopted, that is, by the use of the beds of coal-dust under the layer of sand.

Testing Steel by the Microscope.—John Schott, an eminent chemist, asserts that different qualities of iron and steel can readily be distinguished by means of the microscope. The crystals of iron are double pyramids, in which the proportion of the axes to the bases varies with the quality. The smallness of the crystals and the height of the pyramids composing each element are in proportion to the quality and density of the metal, and these are to be detected also in the fineness of the surface. As carbon diminishes in steel, the pyramids have less height. In pig iron and the lower qualities of hard steel, the crystals approach more closely the cubic form.

Forged iron has its pyramids flattened and reduced to superposed parallel leaves, whose structure constitutes what is called the nerve of the steel. The best quality of steel has all its crystals disposed in parallel lines, each crystal filling the interstices between the angles of those adjoining. These crystals have their axes in the direction of the percussion they undergo in the working. Practically good steel, examined under the microscope, has the appearance of large groups of beautiful crystals, similar to points of needles, all parallel.

Vegetable Parchment.—The common method of preparing this exceedingly useful material requires much care and experience on the part of the operator, and only gives satisfactory results when the strength of the sulphuric acid and length of the process is accurately apportioned to the substance and texture of the unsized paper to be dipped. Mr. Colin Campbell has made a modification of this process, which promises many advantages. Before treating the paper with sulphuric acid, he dips it in a strong solution of alum, and dries it thoroughly. When paper thus prepared is passed through concentrated sulphuric acid, it is converted into parchment paper just as before, but the presence of the alum prevents the action of the acid from being so rapid as before, and therefore renders the whole operation much more manageable. Paper which has been printed on can also be converted into vegetable parchment if treated in this way. The author also proposes to make parchment paper in endless lengths, by connecting the alum and sulphuric acid bath with the paper machine.—*Dingler Polytech. Journal.*, Band CC., p. 509.

Deep Sea Explorations.—An important intimation was made at the meeting of the British Association, by Dr. Carpenter, to the effect that he had communicated with the Chancellor of the Exchequer and the First Lord of the Admiralty on the subject of securing assistance from Government for carrying out a deep-sea exploration. Mr. Lowe had replied that he was favorable to the scheme ; and Mr. Goschen had written a letter, which was read by Dr. Carpenter, in which it was stated that the First Lord of the Admiralty had consulted with his colleagues, and both he and they would give favorable consideration to a general proposal for carrying on exploring operations in the Atlantic, Pacific, Southern, and Indian Oceans.—*English Mechanic.*

The Boatford Bridge, Langholm, N. B., which was only lately finished, fell while about 200 people were upon it. A photographer was in the act of photographing the structure when the catastrophe took place, through one of the chains breaking. The bridge was an iron and wire suspension one of 175 ft. span, and had a very handsome appearance. One or two persons on the bridge received slight injuries.

The Spanish cinnabar mine, at Almaden, is one of the last places where one would expect to find one of Boulton & Watt's original engines, but it appears that one was erected there in 1799, and has been at work ever since.

Submarine Telegraph in Asia.—Telegraphic communication is now open between Shanghai (China) and Nagasaki (Japan).

West Indian Telegraphs.—The West Indian and Panama Telegraph Company (Limited) have just received a telegram announcing the successful laying of the section of their cable between Demerara and Trinidad.

VAN NOSTRAND'S
ECLECTIC
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THE TEMPERATURE TRANSMITTED BY INCLINED INCANDESCENT RADIATORS.

BY CAPTAIN JOHN ERICSSON.

From "Engineering."

The notion has long prevailed that the surface of an incandescent body projects rays of equal energy in all directions. Laplace, having full confidence in the correctness of this assumption, founded upon it the well-known demonstration, proving that the radiant energy which emanates from the receding surface of the sun, possesses greater intensity than that emanating from the central regions of the luminary. But, actual observation having shown that the radiant energy from the sun's border, so far from being more intense, is considerably less than from the centre, the persistent mathematician was driven to the alternative of proving that the retardation produced by the sun's atmosphere neutralizes the assumed increase of intensity of the radiation emanating from the receding solar surface. How completely the ready symbols, manipulated by the great master, establish the truth of his proposition, will be found on reference to "Méchanique Céleste," tome iv., pp. 284-288; the result of the demonstration being that the solar atmosphere absorbs $\frac{1}{12}$ of the entire energy emanating from the radiant surface! Evidently Laplace did not regard solar radiation as molecular energy capable of being converted into dynamic energy, or he would have perceived the impossibility of $\frac{1}{12}$ being absorbed by the solar atmosphere. It is not intended to enter on a criticism of the famous demonstration, but the question is so intimately connected with the subject under consideration that a brief reference to the main points will be necessary to show on what grounds the conclusion was based that, but for the retardation produced by the solar atmosphere, the radiant energy of the luminary would be increased in the ratio stated. Accepting Laplace's assumption that the intensity of the radiation increases with the obliquity of the rays (owing, it is supposed, to the increased number of rays contained in a given section), we must admit that the radiant energy from the regions near the sun's border will be greatly enhanced. And since it has been found by actual observation that no increase of intensity takes place, the inference cannot be resisted that the retardation produced by the solar atmosphere neutralizes the increased intensity occasioned by obliquity. It is evident that this retardation may be determined by calculating the assumed increase of intensity corresponding with the obliquity of the rays; but this calculation, it is also evident, will not show the full extent of retardation, since not only is there no increase, but a considerable *diminution* of intensity towards the sun's border. Hence, the amount of retardation determined agreeable to the theory that the radiant intensity is increased by the obliquity of the rays, will be still further augmented. The reader will readily perceive from this brief explanation, on what grounds Laplace's amazing enunciation is chiefly based, that "if the sun were stripped of its atmosphere it would appear 12 times as luminous."

The foregoing reference to theories promulgated nearly a century ago, when solar radiation was but imperfectly understood, will be deemed irrelevant by those who have not made themselves acquainted with the contents of the recent work on the sun, by Père Secchi ("Le Soleil," P. A. Secchi, Paris, 1870). This eminent physicist, who has devoted more time to the investigation of the subject than any one else, now presents calculations proving that the retardation offered by the solar atmosphere to the passage of the rays, is so great that only a fraction of the radiant heat enters space. He sums up his investigation by the following positive statement: "1st. At the centre of the disc, perpendicularly to the surface of the photosphere, the absorption arrests about $\frac{2}{3}$, more exactly $\frac{63}{100}$, of the total energy. 2d. The total action of the absorbing envelope of the visible hemisphere of the sun is so great, that it allows only $\frac{12}{100}$ of the entire radiation to pass, the remainder, that is to say $\frac{88}{100}$, being absorbed." Persons accustomed to compare mechanical equivalents, especially those who possess practical knowledge of the amount of mechanical power developed by the radiant heat emitted by incandescent bodies, cannot consistently accept Père Secchi's theory. Nor will the assumption that the radiant heat is absorbed by molecular motion in the solar atmosphere be accepted by those who take the practical view of the matter, that the dynamic energy developed by the heat rays projected from the photosphere must enter space, less only the amount of work performed during the passage through the solar atmosphere. Investigations conducted by means of the solar calorimeter (described in "Engineering," July 15, 1870), show that when the earth is in aphelion, the dynamic energy of the sun's radiant heat on entering the earth's atmosphere is 6.35 thermal units per min. upon 1 sq. ft. of surface. The dispersion of the rays when the earth is in the position referred to, being in the ratio of 1: 47,567, it will be seen that each sq. ft. of the photosphere emits at least $47{,}567 \times 6.35 = 302{,}050$ units of heat per min. Secchi says that only $\frac{1}{8}$ of the heat emitted passes through the sun's atmosphere. Accordingly $7 \times 302{,}050 = 2{,}114{,}350$ units per minute are absorbed. Now the development of one horse power requires $\frac{33000}{772} = 42.7$ units of heat per minute; hence the energy supposed to be absorbed represents a *continuous* dynamic force, amounting to $\frac{2114350}{42.7} = 49{,}516$ horse power for each sq. ft. of the surface of the photosphere. Considering that the sun's atmosphere is composed of highly attenuated gases, containing a very small quantity of matter, probably not much more on a given area than the terrestial atmosphere, the assumption that the stated enormous energy is continually being arrested by the solar atmosphere, is utterly at variance with the principles of mechanics. But as it is not our intention on this occasion to combat the erroneous, not to say absurd, doctrines relating to solar heat, contained in the pages of "Le Soleil," let us at once proceed to investigate the subject of radiant heat emanating from incandescent bodies. If we can prove the fallacy of the assumption that radiators emit heat rays of equal energy in all directions, we destroy the principal foundation supporting the false theory which has led to the conclusion that only $\frac{1}{8}$ of the energy developed by the sun penetrates its atmosphere. The subject will be presented in two sections: 1st. Radiant heat emanating from inclined incandescent planes. 2d. The radiation of incandescent spheres, the first section only to be discussed in the present article.

The reader is aware that the experiments relating to the radiant heat of solid bodies, an account of which has previously appeared in "Engineering," were so managed that the atmospheric air was excluded from the radiator and from the thermometer employed. The radiation of flames, it has been shown in previous articles, cannot be ascertained within a vacuum, nor is it easy to confine solid *incandescent* radiators of large size within an exhausted vessel, while ascertaining their radiant power. Some expedient, therefore, must be adopted to prevent the disturbing influence of the surrounding air on the recording thermometer, when experimenting within a vacuum is not practicable. Evidently this can only be effected by keeping the air surrounding the bulb in a perfectly quiescent state. The following description will show the device which has been resorted to.

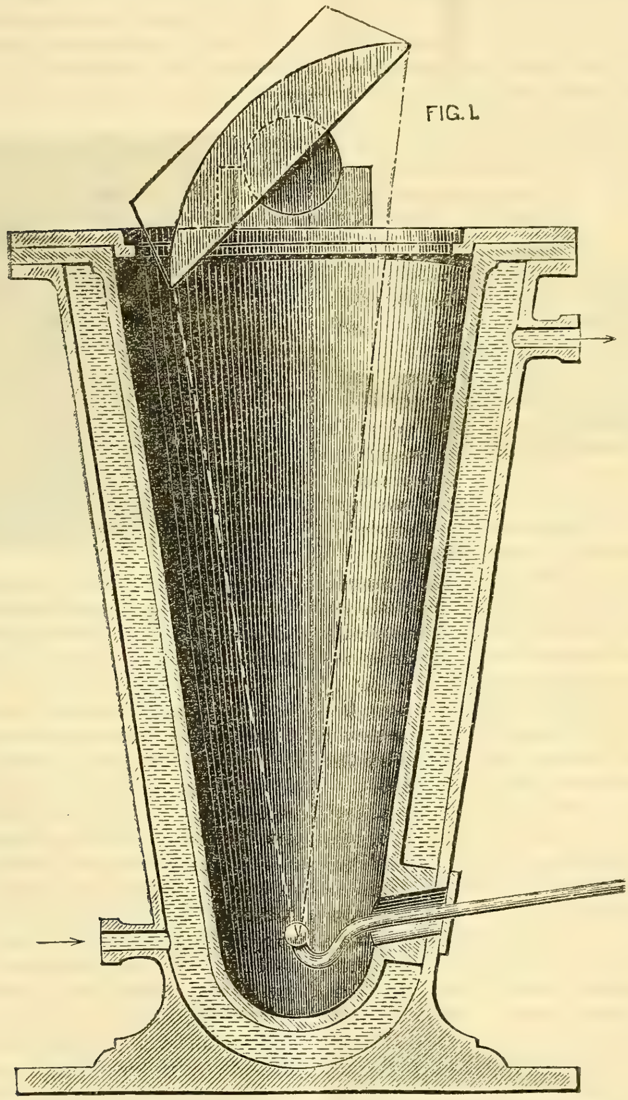
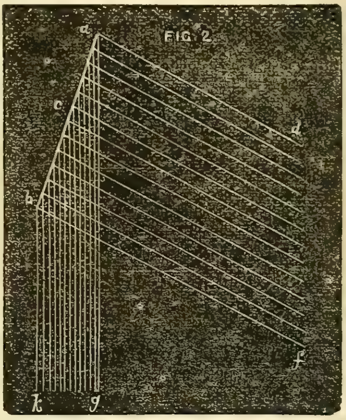


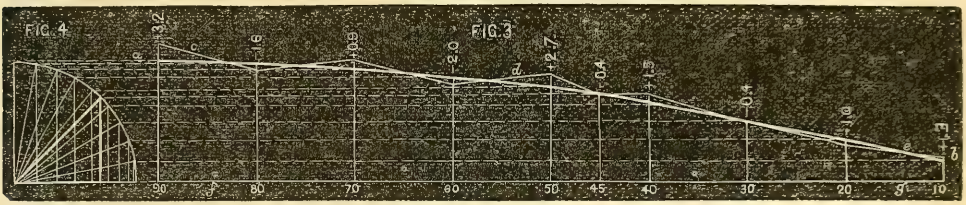
FIG. 1.

Fig. 1 represents a vertical section of a conical vessel, the bottom of which is semispherical, the top being open and provided with a wide flange. A broad ring, with journal bearings attached on opposite sides, is bolted to the flange mentioned; a circular disc of cast iron, the back of which is semispherical, being suspended across the top of the conical vessel, supported by journals resting in the bearings adverted to. A jacket, through which a stream of cold water is passed during experiments, surrounds the conical vessel, the recording thermometer being inserted near its semispherical bottom. The tube of the thermometer is bent, in order that the entire upper half of the bulb may be exposed to the radiant heat of the circular disc, while the lower half is inclosed in a casing composed of non-conducting materials. It scarcely needs explanation that the air within the semispherical chamber containing the thermometer will remain in a quiescent state, since the heat is applied from above. The cold air at the bottom obviously cannot be replaced by heated air from the top. At the same time, the trifling amount of heat carried downward by conduction, from particle to particle of the confined air, will be completely absorbed by the surrounding cold vessel. Consequently, the action of the enclosed thermometer will be sufficiently undisturbed to afford reliable indications. The inclination of the radiating circular disc is regulated by a graduated quadrant and an index secured to one of the journals, in such a manner that it may be readily detached and again applied. A casing, likewise readily secured and detached, is applied to the disc in order to prevent radiation from the semispherical back towards the thermometer, when the inclination is great. During experiments, the apparatus is placed near an air furnace, hose being attached for supplying a constant stream of water through the jacket. The furnace having been charged with combustibles capable of producing a steady fire, and heated to the requisite degree, the disc is inserted. Having remained in the furnace until the color of the metal approaches bright orange, the disc is quickly withdrawn and placed over the open conical vessel, supported by the journals, as shown by our illustration.

Agreeable to the theory, the correctness of which we are going to disprove, the incandescent disc, placed at the inclination shown in Fig. 1., will transmit a higher temperature to the thermometer than if it were placed at a greater angle to the vertical line ; the reasons assigned for this assumption being that the same number of radiating points are presented by the disc, and the same number of rays of equal energy emitted in either position, while in the former they are more concentrated than in the latter. This explanation involves the proposition that parallel rays projected at an acute angle, from a given number of radiating points, transmit *greater* intensity than an equal number of parallel rays projected at a less acute angle to the radiant surface. That this proposition, although untenable, is very plausible, will be seen by reference to Fig. 2. Let *a b* represent the inclined adiant surface, and *a c b* the several radiating points projecting heat rays towards the spaces *d f* and *k g*. The number of radiating points and the number of heat rays projected being alike in each case, while the space represented by *k g* is only ⅓d of that represented by *d f*, it must be admitted, if we assume all rays to possess equal energy, that the concentration of



heat within *k g* is three times greater than within *d f*. In other words, that a given area within *k g* receives three times more heat than an equal area within *d f*. This apparently correct view of the question, and its application to spheres, led Laplace astray in his demonstration concerning solar intensity. In the second part of our discourse, which, as already stated, will be devoted to incandescent spheres, the influence of the spherical form on radiant intensity will be fully considered. In the meantime, we must admit that the demonstration contained in Fig. 2 is unanswerable under the stipulated condition that all heat rays emitted by a radiator possess equal energy. Our task, therefore, will be to show, practically, that the stated condition, is based upon untenable ground. Having already made ourselves acquainted with the apparatus constructed for this purpose, we may at once proceed to consider the results of the experiments which have been instituted. It will be evident that owing to the high temperature of the disc, it will cool very rapidly after being removed from the furnace and placed in position over the conical vessel, and that the thermometer, however sensitive, will require so long a time before reaching maximum indication, that only one inclination can be experimented on at a time, thus rendering reheating indispensable for each change of inclination. The number of changes of inclination during the investigation have, therefore, been limited to ten, beginning with 90 deg., and ending with 10 deg. inclination to the vertical line. It will also be evident that the high temperature renders it practically impossible to impart exactly the same degree of incandescence at each operation. The best that can be done is to maintain the furnace at a uniform temperature, and to expose the disc to the action of the heat during an equal time for each operation. This method, though not precise, has, it will be shown, conclusively established the fact that the temperature transmitted to the stationary thermometer by the radiant heat, varies in the exact ratio of the sines of the angles formed by the face of the disc, and a line drawn from its centre through the centre of the bulb. The result of an experiment made with great care will be found recorded by the diagram, Fig. 3, in which the ordinates of the curve, *a b*, represent the



sines of the angles formed by the disc and the line mentioned, the ordinates of the irregular line, *c d e*, representing the temperature transmitted to the stationary thermometer. The figures inserted below the base line, *f g*, show the number of degrees of inclination corresponding with the sine represented by each ordinate, while the figures above the curve, *a b*, show the discrepancy between the calculated and the actual temperature transmitted to the stationary therm ›meter. It will be found on inspection that the mean difference of the actual and the calculated temperature *above* the curve is 1.94 deg., that *below* the same being 1.08 deg.; hence the mean discrepancy is only 0.86 deg. Fahr. Considering the difficulty of imparting an equal temperature at each operation during the experiments, this discrepancy between the calculated and the actual temperature transmitted by the radiation of the incandescent disc is unimportant. We are compelled, therefore, to accept the conclusion that the temperatures vary exactly as the sines of the angles of inclination of the radiant surface. It has been deemed proper, in view of the great importance of this conclusion, and in order to render the subject clearly understood, to introduce Fig. 4, showing the several angular positions of the incandescent disc during the investigation. Dotted lines, it will be seen, have also been introduced, connecting these angular positions with the corresponding ordinates of the curve *a b*, in Fig. 3. A mere glance at the geometrical representation contained in Figs. 3 and 4, will show that the temperatures indicated by the curve correspond exactly with the sines of the angles of inclination of the disc. Bearing in mind the facts thus established, let us again refer to Fig. 2, in which the space *k g* is $\frac{1}{3}$ of the space *d f*. We are now enabled to demonstrate that the temperature within the former will be only $\frac{1}{3}$ of the temperature within the latter. Laplace and his followers, assuming the reverse to be the case, viz.: that the temperature within *k g* will be 3 times higher than within *d f*, their estimate of the radiant intensity of inclined surfaces will obviously be too high in the inverse ratio of the sines of angles of inclination. The consequence of this grave mistake, with reference to the radiant power of incandescent spherical bodies, will be discussed in the next article on radiant heat.

New York, December 15, 1871.

Dr. Robert Hunter, of Cleveland, Ohio, is reported to have invented a method of propelling canal boats that promises to be highly successful. An india-rubber plate is attached to the stern of the boat and is actuated by steam in the manner of a fish's tail.

BLAST FURNACE ECONOMY.*

By THOMAS M. DROWN.

From the "Bulletin of Am. Iron and Steel Association."

We have learned that it is coal that does the work in the blast furnace, and that the work is twofold; first, reducing; second, heating. The whole question of economy in blast furnace management turns around this point of the amount of coal used.

The history of the iron manufacture exemplifies well the importance of this matter. In the year 1829, there were used in Scotland 8 tons of coal in the form of coke to make 1 ton of pig iron; the amount at the present day has been reduced to nearly 1 ton of coal to the ton of pig iron.

Let us study the subject systematically, so as to learn all the possibilities in the case.

We have already seen that a short distance above the tuyeres only carbonic oxide exists, and no carbonic acid, and that the heat of the blast furnace, considered as a whole, is only that which would be produced by burning all the fuel to carbonic oxide—an amount which is comparatively small. Again, $\frac{1}{2}$ of the fuel is consumed before the tuyeres to carbonic acid, and produces the intense heat necessary for carburizing the iron and melting the iron and slag. Now, it is upon this half of the fuel that the working of the furnace depends. Suppose, for example, that a furnace is working satisfactorily, producing a highly carburized iron and a well melted normal cinder. If the amount of fuel charged be lessened, what will be the effect? There will naturally be less heat before the tuyeres, the iron will combine with less carbon, and will be consequently whiter and more infusible, and the slag will be imperfectly melted.

The question arises, therefore, how can we maintain the same temperature before the tuyeres with a smaller amount of fuel? The means employed are, first, to heat the descending charge; second, to heat the ascending blast.

The charge must necessarily become heated in descending as it meets the hot ascending gases, but in low furnaces the heat of the gases is not completely abstracted and much goes to waste at the top of the furnace. To utilize this heat, the furnace must be made higher so as not to allow the gases to escape until they have transferred nearly all their sensible heat to the charge. The profitable limit of height is therefore attained when the gases given off are comparatively cool.

There is another limit, however, and that is the hardness of the materials of the charge and their ability to resist crushing and packing. The highest furnaces yet constructed are a pair in the Cleveland district, in England. These are 150 ft. high. They smelt the hard Cleveland ironstone with Durham coke, which is noted for its hardness. Crumbling ores like some of the brown hematites, and soft fuel, would be entirely inadmissible under such conditions.

The economy attained in high furnaces, supposing all conditions to be favorable to their use, is very considerable, and the cause of the economy lies mainly in the utilization of the sensible heat of the gases of the furnace.

Besides this direct method of heating the charge, there is also an indirect method, which consists in calcining the ore and limestone, or both, before charging. One of the effects of the heat of the furnace on the charge, as we have learned already, is the driving off of volatile ingredients, as water from the ore and carbonic acid from the limestone; if, therefore, this be effected outside of the furnace, the heat which was before consumed in performing this work will be available for heating. The saving of fuel consequent on using calcined ore and limestone is considerable, but local circumstances must always decide whether it be economically advantageous. Where cheap coal cannot be obtained, or where the additional expense of handling would be great, it may be cheaper to effect the calcination in the upper part of the furnace. The most favorable conditions are present when the calcination can be effected in kilns heated by waste blast furnace gases.

We might mention a third means of

* Extract from a Lecture delivered before the Franklin Institute, Jan. 23, 1872.

economizing fuel in this division, namely, by producing less cinder. The amount of cinder formed in any instance is of course dependent on the amount of earthy impurities in the ore. The more silica we have in an ore, the more lime is required to flux it, and the more fuel is required to melt the resulting cinder. The generality of iron ores are silicious, but there occur not unfrequently argillaceous and calcareous ores, which, when mixed with silicious ores, may give a self-fluxing charge. A cinder is of course formed, but owing to the charge being enriched by the judicious mixing of ores it is smaller in amount, and consequently less fuel is required to melt it.

The saving effected by the additional heating of the charge is, however, insignificant in comparison with that attained by heating the blast. This discovery was made by James Beaumont Neilson, of Glasgow, in 1828. The first apparatus for heating the blast was put up at the Clyde Iron Works, in 1830, and in 1835 hot blast was in use in all the iron works in Scotland. The following account of these early experiments will show the remarkable saving effected. In the first 6 months of 1829, when cold blast was employed, there were used 8 tons 1¼ cwt. of coal, in form of coke, to produce 1 ton of iron. When using 8 cwt. of coal to heat the blast to 300 deg. F., there were used 5 tons 3¼ cwt. coal per ton of pig iron, a saving of 2 tons 18 cwt. To put the same in other words: 8 cwt. of coal burned outside of the furnace and the heat forced into the furnace in the form of hot air was equal to 2 tons 18 cwt. used in the furnace itself. This result was so extraordinary that it baffled explanation, and it is only very recently that this phenomenon has been satisfactorily explained. J. Lowthian Bell, an English iron master, whose researches into the theory of the blast furnace process have been the most painstaking and reliable that we possess, shows conclusively that the cause lies in the fact that the coal consumed in heating the blast outside of the furnace is converted into carbonic acid, that is, we obtain the total amount of heat possible from its combustion, while in the furnace itself the coal is only burnt to carbonic oxide and gives less than ⅓ of the heat it is capable of producing. The figures representing the consumption of coal per ton of pig iron at the present day differ widely from those given above for the years 1829–30. Still the saving in using hot blast is no less marked now than then. The temperature of blast now generally employed is from 750 to 1,000 deg. F., and the saving is about 10–11 cwt. of coke per ton of pig iron.

As has been before incidentally mentioned the waste gases of the blast furnace are collected and burned to heat the blast, consequently no extra expenditure of coal is necessary. Ordinarily the amount of gas obtained is more than sufficient for this purpose, a surplus being available for heating boilers for raising steam. It has been mentioned that it is a very general practice to draw off the gas in part by channels in the upper part of the walls of the furnace, while another part escapes from the middle of the furnace mouth and is wasted. Again, many furnaces are constructed with tops which remain completely closed except in the intervals of charging. A complete utilization of the coal is thus obtained, and no furnace can be said to work with a proper regard to economy, which allows a valuable gaseous fuel to escape into the air. It is replied by the advocates of open-mouth furnaces that the escaping gas is over and above what is needed for heating the blast and boiler. It should then be made to do other work or should not be produced at all. In England, where the old adage of "pence making pounds" is better understood than it is with us, the propriety of saving the small amount of gas which escapes at the moment of charging has been discussed—rather a refinement of economy, but eminently suggestive.

These, then, are the points to be borne in mind with reference to a saving of fuel: First, the production of as small amount of combustible gas as possible; second, the complete and profitable utilization of what is produced. A furnace producing but a small amount of carbonic oxide or of combustible gas, indicates, other things being equal, economical working, and, on the other hand, an excess of carbonic oxide indicates waste. A theoretically perfect blast furnace would be one in which all the coal passed out as carbonic acid, but such a condition of affairs will probably never be attained in practice.

There is still another very interesting

point in this connection having both a scientific and an economic side, which has received but little attention. I have said that $\frac{1}{2}$ of the fuel may be regarded as heating or melting fuel while the whole is available for reduction. Suppose now that the ore should reach the vicinity of the tuyeres only partially reduced, that is, still containing some oxygen, what would be the consequence? This residual oxygen will be taken up by the coal in front of the tuyeres; in other words, the coal which should be used exclusively for heating and melting has to do the work of reduction. One and the same amount of fuel cannot do both, and if, therefore, the duty of reduction be superadded to that of heating, more coal must necessarily be employed.

It is not easy to ascertain in any particular instance whether imperfectly reduced ore reaches this low point in the furnace, as we have no means of inspecting the contents of the furnace near the tuyeres, still many facts point toward the possibility of its occurrence under certain circumstances. Let us study what are the conditions which tend to counteract such a state of affairs. They may be enumerated as follows: 1st. The greater porosity of the ore; 2d. The smaller the fragments of ore; and 3d. The greater length of time the ore is exposed to the action of the reducing gases.

1st. The greater porosity of the ore. We can readily understand that a large hard compact mass of ore would be much more slowly reduced than a porous mass, into the interstices of which the gas could find ready access. Some ores are naturally porous, as some of the brown hematites; others, like the magnetites, are extremely compact. The means employed to increase the porosity of ores is roasting. This acts on hydrous or carbonated ores mainly by driving off water and carbonic acid, leaving them more or less cellular. The action of roasting on hematites and magnetites is simply to produce cracks and crevices into which the gas can penetrate.

2d. The size of the ore masses. It is reasonable to suppose that the larger the masses of ore the longer time will be required for complete reduction. No size can be given as best adapted to all ores or all furnaces, but it is a matter of great importance that all the pieces should be as nearly as possible of one size in the same furnace. There is a limit to the degree of comminution of ores or other materials of the charge. If they are too small, approximating to sand, for instance, the superincumbent pressure will cause them to pack so that the gases cannot get through at all, or the gases may form channels and ascend unequally, reducing some portions more completely than others. Many of the brown hematites come in this fine condition and frequently produce irregular working of the furnace. It would be well in such cases if such fine ores could be made into coherent lumps, though it is doubtful if this could be effected profitably.

3d. The length of time the ores are exposed to the action of the reducing gases, is a very important element in this blast furnace economy. It takes both time and heat to effect the reduction of ore by carbonic oxide. The temperature at which reduction begins is variously stated by different investigators, probably on account of the difference of ores experimented upon. Bell gives 424 deg. Fahr. as the temperature at which the reduction of the Cleveland ironstone begins. Scheerer gives 750 deg. Fahr., Tunner as high as 1,250 deg. Fahr. as the point of incipient reduction. There can be but little doubt that the numbers last given are too high. Bell states that reduction proceeds most rapidly at 723 deg. Fahr. Whatever the most favorable temperature may be, a certain time is necessary for complete reduction. As to the length of time, we can only state that the harder the ores and larger the fragments, the more time will be required. The rate of descent of the charge depends on the rate at which the furnace is driven, that is, on the amount of fuel consumed in a given time, and hence on the amount and pressure of blast. The greater the production of a furnace in a given time, other things being equal, the more economically it works. We cannot, therefore, think of increasing the contact of the ore with the gas at the expense of decreased production. Increasing the height of the furnace can only be effective in this regard as long as the gas at the mouth has a temperature equal or above that which is requisite for the reduction of the ore. There is but one other conceivable mode of making the reducing gas act more thoroughly on the ore, and that is to decrease the velocity of its ascent by widening the furnace, and make the walls expand outwards and upwards. This is the case with all furnaces at the lower part where they expand into the boshes, but in almost all instances the walls incline inward again towards the top. The Rachette furnace is constructed on the principle mentioned, namely, with walls expanding from bottom to top. This furnace has not proved very successful in iron smelting, but its failure —if failure it can be called—cannot fairly be attributed to its expanding walls, but rather to its rectangular section. Lead furnaces built on the Rachette principle proved to be in many respects superior to the furnace form previously in use; but when the rectangular section was abandoned, and a combination made of circular section with expanding walls, the improvement in working and yield was very great, and it seems not at all improbable that the same construction would work equally well in the case of iron. That the descent of the charge would be much more uniform in a furnace of this construction, I think there can be no doubt.

Truran, formerly engineer of the Dowlais Works, was the first to advocate wide mouth furnaces to diminish the velocity of the ascending gases. More recently, Troska, in an able discussion of this subject, has arrived at the same conclusion as Truran, and recommends furnaces with vertical walls from the boshes upward. The same argument which supports his conclusions may, however, be fairly extended to furnaces with gradually expanding walls. Of course, the best angle of construction is a matter which must be determined by experiment, and will differ with different ores. It is interesting to note, in this connection, the fact, long known, that in charcoal furnaces the consumption of fuel per ton of pig iron produced decreased as the angle of the boshes was lessened, which doubtless resulted from the diminished rapidity of the gases in this part of the furnace.

To briefly recapitulate, economy in blast furnace management may be attained in the following directions :

1. Heating the charge.
    a. Direct, by increasing the height of the furnace.
    b. Indirect, by calcining ore and limestone.
2. Enriching the charge.
3. Heating the blast.
4. Complete and profitable utilization of the waste gases.
5. Rendering the ores porous by roasting.
6. Breaking ores to uniform and suitable size.
7. Retarding the ascent of the reducing gases.

PROBLEM OF THE RAFTERS.

By DE VOLSON WOOD.

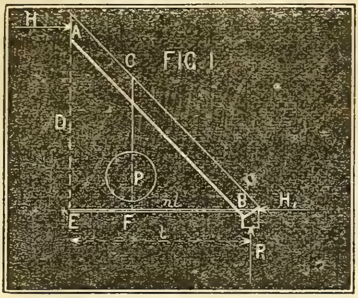
From "Journal of Franklin Institute."

The sloping timbers at the ends of a roof truss are called rafters, whether the truss is a "king post," a "queen post," or other form. When the load is applied at the joints of the truss, the solution seems to present little or no difficulty :—at least authors do not differ in their results. But when the load is uniformly distributed over the rafter, or is applied at points along the rafter, authors differ in their results, as may be seen by examining Trautwine's "Engineer's Pocket Book," pp. 247–252. Mr. Trautwine gives his own solution, and refers to Rankine's "Civil Engineering," p. 470, for the solution which is commonly given. I find, according to the solution given below, that the horizontal pressure at the upper end is the same as that given by Prof. Rankine, but the longitudinal compression along the rafter is not correctly given by any author, so far as I am acquainted with them.

In order to simplify the problem as much as possible, we will at first consider a single rafter supporting a single weight, P, which is applied at any point. The lower end of the rafter, B, is held in the usual way by resting upon a support which sustains the vertical pressure, and by a tie rod which resists the horizontal push. The upper end is held by a horizontal force, which in any case is sufficient to hold the system in equilibrium.

In Fig. 1 let

AB = the length of the rafter.
$D = AE$ = the rise
$l = EB$ = the run of the rafter, or its horizontal projection.
$nl = BF$ = the horizontal distance of the point of application of the weight from B.
θ = the angle $BCF = BAE$.
P = the weight which is applied at C.
P_1 = the reaction of the support B.
H = the horizontal pressure at A.
H_1 = the horizontal pressure at B.



It is a principle of statics that the algebraic sum of the vertical components of all the forces in a system in equilibrium is zero,—and the same is true of all the horizontal components. Or, in this case, the sum of all the forces acting downward, equals the sum of all those acting upward; and the sum of the horizontal forces pressing to the right equal those pressing towards the left. Hence

$$P = P_1, \text{ and}$$
$$H = H_1.$$

Taking the moments about B, we have

$$HD = Pnl$$

$$\therefore H = nP\frac{l}{D} = nP \operatorname{tang}\theta. \qquad (1.)$$

Taking the moments about A, we have

$P_1 l = H_1 D + (1-n)Pl$, or making $P = P_1$, we have

$$Pl = H_1 D + (1-n)Pl.$$

$$\therefore H_1 = nP\frac{l}{D} = nP \operatorname{tang}\theta \text{ as before;}$$

Or, assuming that $H_1 = H$ and we have

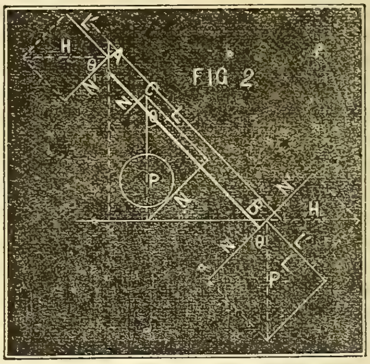
$$P_1 l = HD + (1-n)Pl,$$

in which substitute the value of H from (1) and we have

$$P_1 l = nPl + (1-)nPl$$
$$\therefore P_1 = P \text{ as before.}$$

Next find the compression along the rafter.

Instead of the single horizontal force at A, we may substitute two other forces such that the resultant of the two shall equal H. The two forces will evidently produce the same result as H. As we seek the longitudinal effect, let one of the components be taken in that direction and call it L^1. The other component, to produce no longitudinal effect, must be perpendicular to the rafter. Call it N^1. These forces are shown in Fig. 2.



Hence we immediately have

$$L^1 = H\sin\theta = nP\operatorname{tang}\theta\sin\theta = nP\frac{\sin^2\theta}{\cos\theta} \qquad (2.)$$

$$N^1 = H\cos\theta = nP\operatorname{tang}\theta\cos\theta = nP\sin\theta \qquad (3.)$$

The latter component N^1 produces only bending, and is resisted by a component of the applied weight, P. The former component produces compression only, and is the only compressive force between A and C. At C this force is increased by a component of the weight.

Let N = the normal component of P, and
L = the longitudinal component of P.

$$\text{Then } N = P\sin\theta, \text{ and} \qquad (4.)$$
$$L = P\cos\theta \qquad (5.)$$

Between C and B the total longitudinal compression is

$$L^1 + L = nP\frac{\sin^2\theta}{\cos\theta} + P\cos\theta = \frac{P}{\cos\theta}\left[n\sin^2\theta + \cos^2\theta\right] \qquad (6.)$$

As a check upon the work we may find the reactions of the forces at B.

For H we have the two components

$$L^1 = H\sin\theta.$$
$$N^1 = H\cos\theta.$$

And for P we have

$$L = P\cos\theta.$$
$$N = P\sin\theta.$$

Hence, the resultant longitudinal pressure is

$$L + L^1 = P\cos\theta + H\sin\theta = \frac{P}{\cos\theta}\left[n\sin^2\theta + \cos^2\theta\right] \text{ as before.}$$

The resultant normal pressure is

$$N - N^1 = P\sin\theta - H\cos\theta = P\sin\theta - nP\sin\theta = (1-n)P\sin\theta \qquad (7.)$$

Adding (3) and (6) we have

$$P \sin \theta,$$

which is the same as (4), as it should be, since the normal pressures at the ends should be equal and opposite to the normal component of the applied weight.

DISCUSSION.

1. If the rafter is vertical, $\theta = 0$, and the compression on the upper part, between A and C, is, from (2),

$$L^1 = 0,$$

and the compression on the lower part, between C and B, from (6), is

$$L = P$$

and the horizontal thrust is, from (1), equal to zero.

2. If the rafter has any inclination and P is placed at A, n is equal to 1 in all the equations, and (1) gives

$$H = P \text{ tang } \theta,$$

which is the value given for this case by all writers. Equation (2) gives

$$L^1 = \text{tang } \theta \sin \theta,$$

but, as in this case, C falls upon A, and hence A C = 0, this merely gives the component of H in that direction, and does not give the compression upon any finite length of the rafter. Equation (6) gives

$$L + L^1 = \frac{P}{\cos \theta} = P \sec \theta,$$

which is also the value given by all writers for the compression upon a brace where the total load is placed at the upper end of the brace.

3. If P is placed at the lower end of the beam, $n = 0$, and equations (1), (2) and (6) give

$$H = 0$$
$$L^1 = 0,$$
$$L + L^1 = P \cos \theta;$$

the last of which is the longitudinal component of P; but as in this case C falls on B, the resultant compression does not apply to any finite portion of the rafter.

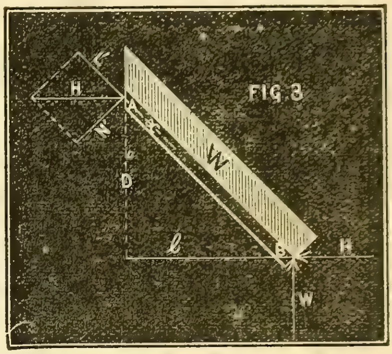
4. Let the rafter be horizontal, then $\theta = 90°$, and equations (1), (2) and (6) become

$$H = \infty$$
$$L^1 = \infty$$
$$L + L^1 = 0 + \infty.$$

5. If P be applied at the middle, $n = \frac{1}{2}$, and we have

$$H = \tfrac{1}{2} P \text{ tang } \theta$$
$$L^1 = \tfrac{1}{2} P \text{ tang } \theta \sin \theta$$
$$L + L^1 = \frac{P}{\cos \theta} \left[\tfrac{1}{2} \sin^2 \theta + \cos^2 \theta \right]$$

By supposing that P is applied at different points, and taking the sum of the results, we may find the effect of several weights applied simultaneously.



Now suppose that the rafter is uniformly loaded over its whole length, and let n = the load on a foot of length of the rafter, and W = the total load.

(Those who compare this solution with Rankine's—"Civil Engineering," p. 470 —will observe that he calls W the load on two rafters, and hence $\frac{1}{2}$ W is the load on one rafter.) Taking the moments about B and observing that the lever arm of W is $\frac{1}{2}\, l$, and we have

$$H\,D = W\,\tfrac{1}{2}\,l \therefore H = \tfrac{1}{2}\,W \frac{l}{D} = \tfrac{1}{2}\,W \text{ tang } \theta. \quad (8.)$$

If x be any distance from A measured along the rafter, $w\,x$ will be the load on that length, and the longitudinal component of it will be, according to equation (5),

$$L = W\,x \cos \theta,$$

and the longitudinal component of H is

$$L^1 = H \sin \theta.$$

Hence the total compression at any section whose distance is x from A, is

$$L + L^1 = w\,x \cos \theta + H \sin \theta = w\,x \cos \theta + \tfrac{1}{2}\,W \text{ tang } \theta \sin \theta. \quad (10)$$

DISCUSSION.

1. At the lower end x = A B, and $w\,x$ becomes w A B = W, and hence *the compression at the lower end is*

$$W \cos \theta + \tfrac{1}{2}\,W \text{ tang } \theta \sin \theta = \frac{W}{2 \cos \theta} \left[2 \cos^2 \theta + \sin^2 \theta \right]$$

$$= \frac{W}{2 \cos \theta} \left[1 + \cos^2 \theta \right] \quad (11.)$$

2. *At the upper end* $x = 0$, and 10 becomes

$$\tfrac{1}{2}\,W \text{ tang } \theta \sin \theta = \frac{W}{2 \cos \theta} \sin^2 \theta = \tfrac{1}{2}\,W \sec \theta \sin^2 \theta. \quad (12.)$$

3. If the rafter is vertical, $\theta = 0$, and (10) becomes

$$L + L^1 = w\,x,$$

which at the upper end is zero for $x = 0$, as it should, and at the lower end it becomes

$$w\,x\,A\,B = W,$$

as it should, since the total load rests upon it.

4. At the middle $x = \frac{1}{2}\,l$, and (10) becomes

$$L + L^1 = \tfrac{1}{2}\,W\,[\cos\theta + \text{tang}\,\theta\,\sin\theta] =$$
$$\frac{W}{2\cos\theta} = \tfrac{1}{2}\,W\sec\theta. \quad . \quad . \quad (13.)$$

5. If the rafter is horizontal $\theta = 90°$, and (10) becomes

$$L + L^1 = 0 + \propto,$$

from which it appears that the compression due directly to the loading is zero; and that due to the resultant horizontal thrust is $\propto$, as it should be in order to support the weight.

Having deduced, as we believe, the correct formulæ for this case, it will be easy to test the correctness of the formulæ which are deduced by others.

Prof. Rankine, in the reference made above, leaves us to infer that the longitudinal compression will be uniform throughout, and finds its value by assuming that one half the load is supported at each end of the rafter. In this way we readily find that the strain would be

$$\tfrac{1}{2}\,W\sec\theta$$

which compared with (12), (13) and (11) shows that it is too great at the upper end, correct at the middle, and too small at the lower end. If the rafter is vertical the above expression gives $\frac{1}{2}$ W for the compression, whereas it should be zero, and at the lower end it is only half enough. The horizontal thrust at the upper end, by this method is $\frac{1}{2}$ W tang θ, which is the same equation (8).

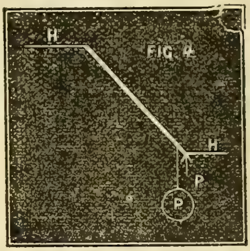
Trautwine considers that the total pressure at the foot of the rafter is a vertical force producing compression. This resolved horizontally and obliquely gives

$$H = W\,\text{tang}\,\theta$$
$$L + L^1 = W\sec\theta$$

both of which are double the value given by Prof. Rankine, and the former is double the correct value.

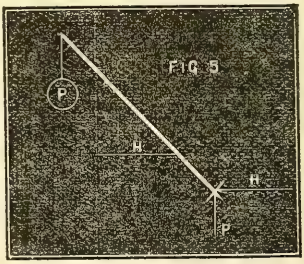
This method at first appears so plausible, that it may be advisable to show its fallacy by an illustration.

If P is very near the lower end of the rafter, as in Fig. 4, it is evident that H will be small, while the reaction is still equal to P; and if the weight P is exactly over the support it will develop no horizontal thrust, but in all these cases, according to Trautwine's formula, the horizontal thrust is the same. The longitudinal compression due to P *directly* is



constant for all positions of P for the same inclination of the rafter, and is P cos θ; but the compression due to H is dependent upon the position of P, being small when P is near B. Observe that P may be constant and H may have all possible values depending upon the position of P.

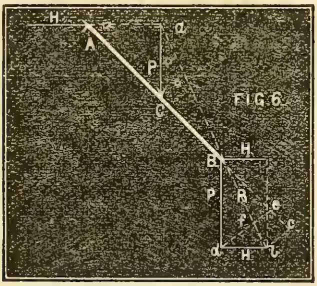
If P is considerably above H, as in Fig. 5, the lower end still sustains P and the horizontal thrust greatly exceeds that in Fig. 4. The compression in this case due to P is the same as in the preceding case, while that due to H greatly exceeds that in the preceding case.



It is worthy of note that the strains in this rafter are independent of the inclination of the rafter, brace, or beam, which holds its upper end in any practised case, *provided* that the two *rest against* each other.

But these illustrations only show the general fact by passing so near the limits of the problem as to make the result appear absurd, but I think they will make the following solution more easily understood. The seat of Mr. Trautwine's error consists in assuming that *the resultant of the two forces at the foot of the rafter is in the direction of the rafter.* This hypothesis is true only when the weight rests upon the upper end of the rafter. The true direction of the resultant may be found geometrically as follows:

Let P, Fig. 6, be applied at any point, then since H and P are in equilibrium about B, the resultant of P and H must pass through that point. It must also pass through the point a, where their line of directions meet. Hence a B is the direction of the resultant. If this resultant



be resolved parallel to and perpendicular to the direction of the rafter, the former will give the compression between C and B, due to H and P. We have from equation (1) $H = n\,P$ tang θ, hence the resultant,

$$R = \sqrt{H^2 + P^2} = P\sqrt{n^2 \text{ tang}^2\, \theta + 1} = \frac{P}{\cos\theta}\sqrt{n^2 \sin^3\theta + \cos^2\theta}.$$

To resolve this multiply it by the cos of b B c. Erect $d\,e$ and $b\,c$ perpendicular to B c, and $b\,f$ perpendiculer to $d\,e$. Call B $d = 1$, then from,

$$d\,b = n \text{ tang}\,\theta$$
$$d\,B\,c = \theta = f\,d\,b,$$

$$\therefore b\,B = \sqrt{n^2 \text{ tang}^2\,\theta + 1}$$
$$B\,e = \cos\theta, \text{ and}$$
$$f\,b = e\,c = n \text{ tang}\,\theta \sin\theta.$$
$$\therefore B\,c = n \text{ tang}\,\theta \sin\theta + \cos\theta. \text{ and}$$
$$\cos b\,B\,c = \frac{n \text{ tang}\,\theta \sin\theta + \cos\theta}{\sqrt{n^2 \text{ tang}^2\,\theta + 1}} = \frac{n \sin^2\theta + \cos^2\theta}{\sqrt{n^2 \sin^2\theta + \cos^2\theta}}$$

The last expression is found by multiplying the terms of the preceding fraction by cos θ.

The total compressive force is found by multiplying the value of R given above, by the cos of b B c as just found. This gives

$$\text{Compression} = \frac{P}{\cos\theta}\sqrt{n^2 \sin^2 + \cos} \times \frac{n \sin^2\theta + \cos^2\theta}{\sqrt{n^2 \sin^2\theta + \cos^2\theta}} = \frac{P}{\cos\theta}\left[n \sin^2\theta + \cos\theta\right]$$

which is the same as equation (6).

If the rafter is uniformly loaded the resultant of the load would pass through the centre of the rafter. Calling the load W and proceeding in the same way as above, we find for the *resultant compression at* B

$$\frac{W}{\cos\theta}\left[\tfrac{1}{2}\sin^2\theta \cos^2\theta\right]$$
$$= \frac{W}{2\cos\theta}\left[\sin^2\theta + 2\cos\theta\right]$$

which is the same as equation (11.)

The compression at any point may be formed in the same way by considering the resultant of the weight between A and the point.

ON THE CYLINDERS FOR THE ALBERT BRIDGE.*

After some introductory remarks, Mr. Kingsford described the general *modus operandi* of ordinary loam-casting in a foundry, that being the method by which the cylinders for the Albert Bridge are being produced. As this will be familiar to most of our civil engineering readers, and as our space is limited, we pass on to give the substance of the immediate subject of the paper. In the arrangement of the piers, as originally designed by the engineer, Mr. Ordish, it was intended to build up the external casings with cast-iron flanged plates, bolted together in cylinders, the piers when complete to be filled up with concrete. The lower portion of each pier was to be 21 ft. in diameter for the first 9 ft. in height, and from thence the piers were to be contracted to 15 ft. diameter by means of tapering plates for another 9 ft., and from thence to the roadway the piers were to have a diameter of 15 ft. The circumference of the lower part was to have been cast in 12 segments, each plate to be 9 ft. high; the upper parts of the piers in 8 segments; all the flanges, both vertical and horizontal, were to be bolted together and caulked. Plates of these dimensions require to be cast with great care in order to keep them from buckling in cool-

* From a paper read before the Civil and Mechanical Engineers' Society, by Mr. C. Kingsford.

ing, otherwise a great deal of labor is wasted in chipping and adjusting them to bring in the bolt-holes, and this would have to be done in the river, causing great delay and expense. It would have been impracticable to transport such large castings as 21 ft. cylinders from the country, but the Battersea Foundry being situated so close to the proposed bridge, Mr. Kingsford thought it quite feasible to attempt to cast them in rings or cylinders in loam, instead of in plates as at first proposed, and he mentioned it to Mr. Ordish, who agreed that it would be preferable if practicable. Before undertaking, however, such large castings, there were several very essential points to be considered. The foundry at Battersea is 150 ft. long by 75 ft. wide ; the portion specially set apart for loam work is traversed by a travelling crane of 30 ft. span, carried by the external wall on one side and by a row of columns and girders running down the centre of the foundry on the other. The cupolas (3 in number) are situated at the end of the traveller's run. The only available portion of the loam ground that could be set apart for the purpose of casting these cylinders was about 80 ft. by 30 ft. under the traveller, as none of the cranes would be powerful enough to lift such heavy cores and castings. The space necessary to build the cope for the 21 ft. cylinders would be at least 30 ft., and nearly the same for the core ; thus 60 ft. of the 80 ft. would be disposed of, leaving only 20 ft. for the 15 ft. cylinders. It was neccesary, therefore, to arrange for casting them alternately, building first a 21 ft. core, and then a 15 ft. core in the same ground, thus economizing space. The next point for consideration was how to get the castings out of the foundry, as it was quite evident at a glance that they must be got out on edge, as the doors were only 15 ft. wide, and could not be widened without endangering the superstructure. There was sufficient height, fortunately, to enable them to be lifted clear of the ground in this position, and rolling them down to the water's edge suggested itself as the best mode of delivery. These questions ascertained and settled, Mr. Kingsford's suggestion, that the piers should be cast in cylinders instead of in plates, was adopted. The production of such large castings is in reality a matter for the civil engineer quite as much as for the founder, for whereas in most cases the foreman at the foundry is left pretty much to his own resources and ingenuity to construct as he pleases his own tools and appliances, in this case it was not necessary for the engineer to aid him in well defining and reducing to accurate calculation the several strains likely to be met with and provided against in the construction of the mould, and the whole was thoroughly digested and laid down on paper before commencing the work. In spite of all these precautions, however, the strength required was underestimated, for the first cast was a failure, the brickwork in the core being too weak and giving way to the pressure of the metal. It was feared that the traveller was of insufficient power to carry a core of the size required with a wall of brickwork 9 in. thick, and which, it was calculated, would weigh, with the necessary iron in it, very nearly 18 tons ; so the core was made of 4½ in. work, with piers about 5 ft. apart, and its weight did not much exceed 10 tons. Every other detail appeared to be satisfactory. It was necessary to provide against the pressure of the metal on the walls of the cope; the cope was therefore built in the ground, of 9-in. brickwork, well rammed up all round to the level of the surface; for although the core had to be broken down for each casting, the cope, as far as the brickwork was concerned, remained permanent, and served for all the succeeding castings of the same form and size. When the pit was dug the loam-ring was laid in position, and upon this the wall was built. These rings were generally cast in one piece, but, for want of space in the foundry at the time, the ring was made in three segments, and bolted together ; and as it was proposed to cast the conical cylinders in the same pit, a strong cast-iron cross was provided, and laid permanently at the bottom of the pit, with its twelve arms passing under the loam-ring, so that it could be used to bolt down the conical cores without interfering with the cope of the first cylinders. The loam-ring for the cope was 18 in. wide and 2½ in. thick, and cast with twelve lugs round the circumference, to which lugs were attached the tying-down bolts, consisting of 1½ in. round rods, forged with stirrups fitting the lugs of the loam-ring. The weight of metal in the ring and cross amounts to about 7 tons. The cope was built up of 9 in. brickwork, with binding plates set in the joints at about every 6 courses. The plates were $\frac{3}{4}$ in. thick, and 9 in wide; the walls were well rammed up all round and thoroughly dried. Thus far the structure is permanent, and remains *in situ.* The walls are faced inside with a coat of loam struck up in the ordinary way by means of the loam-boards ; these, however, from their extra weight and size, required to be counter-balanced, otherwise the process differs in no way from the general plan adopted in all like cases. In striking up the cope a seating of about 6 in. in depth is formed at the bottom of the mould; a similar seating called a dummy is also formed on the floor where the core is to be built up; this seating serves for all the succeeding cores ; the core being constructed on this dummy, corresponds exactly with the seating at the bottom of the cope, and when placed in position is guided by it into the centre, leaving the desired space all round for the metal. The core is made on a ring cast rather smaller than the seating, with 8 wrought-iron loops cast in, by which the whole is lifted and placed in the cope; upon this ring are 8 segmental plates, which carry the brickwork. These plates are clamped together, forming one ring, but as soon as the casting is made the clamps are knocked away, and the plates set free to allow for the contraction of the metal in cooling. At every 6 courses in the wall are binding plates in segments to strengthen the work, and the brickwork is 9 in. thick all over. The core thus constructed weighs 18 tons. In the first or lowest cylinder a curved moulding is formed on the bottom edge, for as no flange is here required it was thought advisable to strengthen the edge which bears on the ground and carries the weight of the superstructure; and at the same time something of the sort was required to equalize the metal, so as to avoid the chance of a fracture from any irregularity in the cooling. All these cylinders, it must be stated, are cast the reverse way to the position in which they will stand in the piers, in order that they may be relieved from the mould without breaking down the cope. The covering plate, which is cast in three segments, is struck up to the form of the bottom moulding of the cylinders; this, from their being reversed in the mould, being at the top, it corresponds with and fits into a seating formed on the top of the cope, and is cast with 33 holes, 30 of which serve for the runners, and 3 for the risers. These segments were capable of being dried in the stoves; but in order to dry the rest of the work, "portable kettles," as they are called, are employed ; in these, gas-coke is burnt, and of course this is not so economical as drying in stoves ; but the stoves at the Battersea Foundry will not take in a mould more than 14 ft. wide. When the bricks and loam are dry, the face of the mould is blacked, and then again dried, and the mould is then put together. A cast-iron cross having 12 arms is laid over all, and tied down by the 12 $1\frac{1}{2}$ in. bolts surrounding the cope. In making up the mould a sow or trough is formed, composed of sand and confined between two rows of jointed plates, called cribs, fixed on edge all round the top of the mould. In this sow are 30 runners of about $1\frac{1}{4}$ in. diameter, leading perpendicularly through the holes in the covering plate down into the mould between the cope and core. Three other holes of similar size, which serve as risers, are stopped off from the runners on the one side of the mould. Three basins communicating with the sow are formed to receive first the metal from the ladles. The metal when poured is thus conducted into the mould in 30 small streams, which insures a uniform flow to all parts at once.

The calculated weight of the casting is about 9 tons, but as it is always desirable to have metal enough, and to spare, it is run from 3 ladles, a 6 ton, a 4 ton, and a 3 ton, making in all about 13 tons of metal. The arrangement adopted of pouring the metal out at 3 founts is very satisfactory. The largest ladle is served by the traveller, and the other 2 by the cranes, one being close to the work, and the other about 12 ft. off, from which the metal flows to the mould along a trough. The metal is melted in 2 cupolas, one 3 ft. internal diameter, and the other 2 ft. 6 in. The largest cupola has 3 tuyeres, the smaller one 2. A pressure of 7 in. of blast was got with one of Lloyd's 30 in. fans, driven by an 8-horse engine, and the 13 tons of metal was run down in about an hour and a half. A mixture of $\frac{1}{4}$ pig iron and $\frac{3}{4}$ best machine scrap is employed, which produces a metal extremely strong and suitable for the purpose.

The conical castings forming that portion of the piers of the bridge which reduces the diameter from 21 ft. to 15 ft. require rather a different arrangement with regard to the building-up of the core. The angle of the cone is so great, contracting as the cylinders do 3 ft. on each side in a height of 4 ft. 6 in., that it would be impracticable to lay on the loam overhead, as it were; it would not have adhered to the brickwork, but would have fallen off as soon as the board left it. The plan was therefore adopted in thicknessing up the cope and building the core within it. The cope of the conical cylinders is built inside that of the parallel ones, as there are some more to cast after these are done. When the cope is struck up in loam and dried, a thickness of wet sand, corresponding with the thickness of the casting, is laid on and struck up with the core-board and dried. The core is then built inside the cope, and when dry is lifted out and dressed, and the thickness of sand removed; in all other respects the casting is conducted as usual, except that as these castings present more surface on plan, they require extra holding down, which was effected by means of cast-iron clamps on the inside, in addition to the 12 external tie-bolts. The 15 ft. cylinders are made in every respect in a similar way to the 21 ft. ones, allowance being made for the difference in size only. They weigh only about 7 tons, and it takes a week to prepare each mould.

Mr. Kingsford concluded his paper by some remarks on the estimation of the several strains that are set up in moulds during the time of pouring in the metal for these large castings. In the case of the 21 ft. cylinders the width of the flange was 4 in., the circumference being 66 ft., giving an area of 22 sq. ft., multiplied by 4 ft. 6 in., the height of the cylinder; this equals 99 cubic ft. of displacement, and as a cubic foot of iron weighs 4 cwt. there is about 20 tons exerting itself to lift the core. In the conical castings the flotation is considerably more. The difference of areas between the cylinder at the bottom and top of the mould represents about 190 sq. ft.; this, multiplied by 4 ft. 6 in., the height, gives 855 cubic ft. of displacement, being equal to 170 tons. From this we must deduct about 20 tons for the weight of the core, which represents a vessel floating in liquid iron, and 150 tons is the upward pressure on the tying-down bolts. There are 12 $1\frac{1}{2}$ in. bolts, equal to 27 circular in., 10 tons to a circular in. being generally considered safe. This gives 270 tons, which should be sufficient; but in order to be on the safe side, the mould is clamped on the inside, which greatly adds to its rigidity, the object being to guard against the mould straining, as much as possible. Besides the actual strain from the pressure of the metal exerted to float the core, there is the lateral pressure on the walls of the core and cope. The cope being in the ground and well rammed up, may be passed by as safe, but the core requires very careful construction. Eight of these cylinders, out of about 30, have been cast. The core of the first, as before stated, was not sufficiently strong enough to bear the weight of the metal against its sides, and it gave way. The second strained so much that instead of its thickness averaging $1\frac{5}{8}$ in., as it ought to have done, it averages 2 in., and weighs 12 tons. The succeeding ones have not strained much, but the lightest is fully $\frac{1}{8}$ in. thicker than it ought to be, and Mr. Kingsford believed that, in order to cast them without straining in the least, the walls of the core would have to be 18 in. thick, and the core would weigh upwards of 30 tons.

Now that it is possible from practice, however, to judge the amount of the strain in the castings, it was allowed for, and the remaining cylinders will be nearly correct as to thickness. Another cause of straining is the pressure of the suddenly heated air in the mould as soon as the melted iron is run in. This is not so easily calculated; but it is necessary, in order to have a good sound casting, free from scabs, that the air should be thus confined. The metal enters by 30 runners, and the same quantity of air, greatly augmented in bulk, has to escape through 3 risers, which it does, in all probability, at a pressure of nearly 15 lbs. to 1 in. If so, it would just about double all the strains, for 1 in. of iron, 4 ft. 6 in. high, equals about 14 tons or 15 tons.

ARCHITECTURE FOR ENGINEERS.*

After some introductory observations, Mr. Rew remarked that the right understanding of the principles of architecture by engineers was of the greatest and most varied consequence and value. That English engineers had carried out works of great value and importance in almost every country in the world was a fact to be proud of, and while it was to be hoped that great works, even surpassing those that had been accomplished, were yet to be achieved by them, it was to be trusted that such future works might approach as near to the artistic beauty as the past ones did to scientific and mechanical perfection. Up to the present, if our mechanical architecture had been bad, our "engineering" architecture (if the expression might be used) had not been all that could be desired. Some of the railway bridges over the Thames, for instance, did not convey the idea of abstract and perfect beauty, while the preposterous roofs of our great terminal railway stations seemed first of all to suggest "how much you are in the open air when standing on the platforms under them." It seemed ridiculous to build such enormous roofs where headway was only wanted for the funnels of the locomotives. If it were argued that, to cover so great an area with a roof of one span, such a great height was a necessity, and that to divide the same area into portions by rows of columns was bad economy of space, it might be said, in reply, that admitting the argument of economy (which was, however, an open question), the gain of a little more space in the platforms was very dearly bought by the frightful appearance of these large roofs from the outside. As for bridges, Mr. Rew feared that until the time came, when engineers should turn their attention to building them of stone again, or at least until stone piers took the place of iron cylinders, papers on "architecture for engineers," would at least be premature; for, anything more utterly above or below careful criticism than structures with no more artistic beauty than the Chatham and Dover Bridge at Blackfriars, or the South Eastern Bridge at Charing-cross, it would be difficult to imagine. In the new Blackfriars Bridge there was at least one great step in the right direction—viz., the adoption of piers of masonry, instead of the ill-proportioned and dropsical iron columns seen in the railway bridges mentioned. But even in Blackfriars bridge the columns (or pulpits) standing on the cutwaters offended against the first law of good architecture—the law of Truth. Why those columns should be of their present diameter, with only a light parapet to carry, it would puzzle the architect, if not the engineer, to tell. Another, but smaller fault, was the absence of a moulding of some sort or other under the brackets or trusses to the cornice of the bridge; as they now were, they appeared to be supported by the very part they were meant to strengthen. These were examples which went to show that there were many points where great improvement was possible. It was, therefore, worth while to try to discover some of the simple (but too often neglected) principles in the application of which good architecture consisted, and to the application and understanding of which any improvement æstheticially of our engineering works (if it was to be made at all) must be mainly due. The subject would be better appreciated by starting with a clear understanding of what was really meant by the word "architecture" as distinguished from "building," for the things meant were quite distinct from, although often associated with, each other. It was quite possible to have a building covering a large area, yet quite innocent of anything that could be called architecture. The building, so to speak, was the constructed skeleton; the architecture was that which determined the exact outward appearance of the perfect body. To build was literally to erect or construct—to fit and apply each material in the form and position most suited to its capabilities and nature, and so as to get the most work out of the smallest quantity of material; but, in the words of a modern writer, "building does not become architecture merely by the stability of what it erects, and it is no more architecture which raises a church, or fits it to receive and contain with comfort a required number of persons occupied in certain religious offices, than it is architecture which makes a carriage commodious or a

*A paper read before the Civil and Mechanical Engineers' Society by Mr. C. H. Rew.

ship swift. That is church-building, coach-building, or ship-building, as the case may be, but it is not necessarily architecture." It had been well said that architecture was "the adding of unnecessary features to a building." For instance, if a stone bastion were erected—that was building; but if a projecting course of masonry was left near the copping, and caused to represent a cable—that was architecture. Or if an arch was thrown over a door or window opening—that was building; but if the arch stones were moulded or carved, that moulding and carving was architecture. Therefore, while there could not possibly be architecture without building (or, for that matter, *good* architecture without *good* building), it was quite possible to have building in which architecture was wholly wanting. Among the leading principles which distinguished good from bad, whether in architecture or building, firstly, and at the head of all, came the law of common-sense, or Truth. When this was wanting the building or architecture in question must be bad—utterly past amendment. No architecture or building which was a sham was worth anything but contempt. But if, on the contrary, having regard to the fundamental law of truth, a building was first of all planned, with each portion or room in its natural place, and where, from its intended use or connection with other parts, one would expect to find it, much had been done towards obtaining a good building. If the walls were solid and good, the doors and windows, and other subordinate parts, so grouped and placed as to weaken the walls in the least degree possible, another step had been taken in the right direction. If the roof was arranged to cover the building in the simplest and least complicated way, instead of, as was sometimes done, making it as elaborate and eccentric as possible, as if the designer had taken delight in getting into little dilemmas just to show how clever he was in getting out of them, still further was done in the right direction. And if the eaves were brought well over the walls, and the chimneys carried well above the roof, the designer would be rather a genius than otherwise if the result was not something in the shape of a good building. Again, the subject might be yet further gone into by considering the use and nature of the materials employed. As regarded stone, as stone, the geological arrangement of the rocks was the surest guide to the right arrangement of the stone in the different stories of a building. Granite, which (speaking geologically) was the lowest or base stratum or system, naturally suggested itself as most appropriate in the lower stages of a building, or in any portion where great weight had to be sustained. As for the working of the individual blocks, the safest rule was to use the stone as soon as it was worked to the required shape, for whatever was done more was just so much ruination to it. In nine cases out of ten more labor was wasted in what was called "finishing" stonework than was spent or required to be spent in working it to the required form. People wondered why modern stonework looked so tame and lifeless. Writer after writer had pointed out that in the old masonry the stonework was "rough and ready;" yet in practice, they would not be content with having stonework wrought into shape or *done*, but over and above that, it must be finished. And most thoroughly finished it was, so far as having any life or beauty left in it. As an instance, during the rebuilding of St. George's Church, Doncaster (one of the first in point of time, as well as of merit, of modern attempts at restoration), an argument was in progress between some members of the Restoration Committee, during a visit to the masons' yard, as to why the new stonework persisted in looking so tame, although the masons were working it as nearly as they could to the old sections. Nobody could tell until one of the committee happened to see a piece of moulding lying on a block. That, they all exclaimed, was exactly what they wanted, but they were corrected by the mason saying, in a tone of pitying condescension, that it wasn't "finished." That explained the whole secret, and no more "finishing" was allowed, the result being all that could be wished. Again, in the use of brick, the rule at the bottom of it all (and the infringement of which caused a very large proportion of architectural failures) was to "let a building look as if it was a brick building, and not a stone one." Brick, if rightly used, was as honorable a building material as stone, and quite as much (if not more) capable of being its own decoration. In London, brick, according to the doctrine of locality, was the right material to use, and was strictly speaking, "the indigenous building-stone of the neighborhood." As instances of what could be done in brick architecture, Mr. Rew referred to the buildings on the east side of King's Bench-walk, in the Temple, and (of modern work) the small church of St. James's the Less, and the more ornate one of All Saints', Margaret street. Among the ways in which brick was misused was that of attempting, by grouping the courses, to give the idea of large blocks of stone. This was sometimes done by setting back every seventh course or so from the ordinary plane of the walls, the intention being to convey the idea that the six courses formed a single course of stone, and that the seventh was the joint. The same thing might be done by placing at regular intervals a double course of chamfered bricks. Another and very common thing was to see the wall built of one kind of bricks, and the jambs and quoins of another. All such proceedings were directly opposed to the fundamental rule of truth and common-sense, for, taking the last example of the quoins, the mistake was not in putting the better material where there was more work to do or more exposure to bear, but in making it pretend to be what it was not. Just in the same way that in masonry one sort of stone was used for the ordinary walling and a harder and better kind for the quoins, where the means at disposal would not allow the better stone only to be used, so, in brick-work, it was perfectly rational to use an inferior sample of brick in the walls, with a harder and firmer kind for quoins. But doing this honestly was a different thing to building quoins of brick that looked at a little distance as if they were stone, if bad and false. It seemed to the author that it might be taken as an axiom, that the first step towards the right use of brick as a building material was to put utterly out of mind the notion that brick was *only* to be regarded as a cheap and nasty substitute for stone, and only to be tolerated where the funds at disposal would not admit of the latter material. He did not, however, object to the use of brick and stone in the same building, for, of course, there were portions, such as columns, with their bases and capitals, brackets, corbels, and, in fact, all parts meant ultimately to be moulded or carved, for which stone was the only suitable material; but they should show at once, by their position and use, that they had a reason for being of stone, and should not leave room for the idea that it was a mere freak or question of the moment with their designer as to which they should be. Of timber and iron there was not so much to be said as at first sight appeared. As regarded timber, its use was becoming almost a thing of the past, so that there were not so many chances of making mistakes as its more frequent use would afford. As the subject of ironwork was exhaustively treated of in a paper read before the Society last session by Mr. Driver, he (Mr. Rew) need not dwell on that subject on the present occasion.

As to the artistic part of his subject, Mr. Rew said that the first great characteristic which should be kept in view was what was meant and understood by the term "proportion." In order to attain this, it was necessary, according to Mr. Ruskin, to have one large thing and several smaller things, or one principal thing and several inferior things, and to bind them well together. "Sometimes," said Mr. Ruskin, "there may be a regular gradation as between the height of stories in good designs for houses—sometimes a monarch with a lowly train, as in a spire with its pinnacles—the varieties of the arrangement are infinite; the law is universal. Have one thing above the rest, either by size, or office, or interest, and the rest subordinate to it as their relative size or office demands, or anything like proportion is an impossibility." Another sure sign of good architecture was change or variety—*i. e.*, designing each portion, wall, roof, arch, door, or window, with care and study, suiting its form, size, and decoration to its use and office in the building, thinking no part too mean to be deserving of the architect's best work, and as far as possible removed from the more generally accepted principle of making one detail drawing do for as many duplicates as possible—an arrangement of evident advantage in taking out quantities, but as evidently fatal to the architecture of a building. The work of the artist-architect should bear at every point traces and proof of the pleasure caused in the process of designing it. There was one class of buildings, of the first importance to engineers, that, according to Mr. Ruskin, should never be decorated at all, but should be wholly devoid of anything like ornament. Why this sort of argument, however, should apply to railway stations more than to other buildings where business had to be transacted, it was difficult to discover. The next great consideration in obtaining effect in architecture was that of shadow and shade. On the right application of this law depended almost wholly the effect and explanation of grouping. The "power" of architecture depended almost entirely on the breadth and depth of its shadows. A walk round the cloisters of Westminster Abbey on any bright summer afternoon would show how much their effect depended on the broad masses of clearly-defined shadow. The foregoing were some of the guiding rules which conduced to the attainment of good architectural effect, but, as he had stated, the first great essential was common sense, or truth, meaning thereby the absence of anything approaching either to affectation or deceit—and this in the quality or nature of the material no less than in the amount of labor bestowed upon the work. "We may not," to again quote Mr. Ruskin, "be able to command good or beautiful, or inventive architecture, but we can command, at least, honest architecture. The meagreness of poverty may be pardoned, the sternness of utility respected, but what is there but scorn for the meanness of deception?" Never to gain effect or to make work look quaint should this "meanness of deception" be resorted to; never to suggest a mode of structure other than the true one; and the surface of one material should never be painted to imitate the surface of another. If marble chimney pieces could not be afforded, be content with stone, slate, or wood, but do not paint them to represent marble. In the case of woodwork, if mahogany or walnut could not be afforded, be content with deal, only let it suffice to varnish it, or paint it some inoffensive flat color, instead of making people believe it was maple or wainscot oak by the use of the abomination known as graining. This principle of honesty was to be shown in many other ways, notably in the application of enrichments or decorations to returned or partially hidden surfaces. In parts of a building bearing ornament, it was not good architecture to stop it in portions only partially seen, unless some bold and openly confessed termination was put, telling the spectator plainly that it did not stop, and not leading him to suppose that even the less prominent parts of the composition had been decorated.

To have good architecture, one must start with all the circumstances and requirements of the building in view. For instance, this window or that door demanded, from its relative importance, a certain amount of architectural treatment, which should be given it, not so much regarding its actual position in the building as the dignity of the functions it had to fulfil. This rule also applied to the "members" or component parts of the ornament, and we might always estimate its lasting value by the amount of rightly directed labor spent upon it—for it was sympathetic labor that alone gave worth to ornament of any kind. There should be no decoration at all unless it could be had good, and to have it so time and skill must be expended upon it. Any attempt to reproduce ornament cheaply, and by means other than labor and thought honestly bestowed, was to be avoided wherever good architecture was required. A building might be ever so plain, and yet its architecture might be good in the highest sense of the word. Salisbury Cathedral was much nobler architecture than Henry VII.'s Chapel or the new Palace of Westminster, although the one was almost as devoid of ornament as the others were smothered with it. It might be safely taken as a principle that those portions of a building that derived the most interest from their form were those that could best do without superadded decoration. In the case of a series of pointed arches, for instance, it would be much better to let the arches depend for their interest on the curves to which they were struck, and to put such decoration as was at command into the otherwise rather uninteresting spandrel, than to have an elaborately moulded and parti-colored arch, and a perfectly dull and monotonous surface in the spandrel. The common practice, too, of having the capitals of columns so elaborately carved, in many cases where everything was plain, was a very great mistake. Given, then, all these tests of good architecture, in what style were to be found the largest number of them to put to ordinary use? His answer was our own English Gothic. Discarding copyism after a careful study and attempt to discover the principles of common sense and mechanical science in construction, and the correct application of ornament, architects should carry them out in their own work and practice. English architecture was the fitting companion and accompaniment of English engineering, and would be all the more so as it consisted of and rested upon that constructive science in the application of materials ready to hand, which was the very essence of engineering.

THE PRESERVATION OF IRON SURFACES.

From "The Engineer."

Although it might be injudicious to pass comments on the Megæra case, *per se*, whilst yet the investigation is going on, yet in so far as testimony bears upon the preservation of iron structures generally, we make no apology for offering some remarks suggested by revelations which have already been made. The agencies conducing to the disintegration of iron merit the fullest consideration. Some cases of wear and tear involve only questions of expense ; of the wearing out of a substance renewable at a cost greater or less, no question of safety to life or limb coming upon the field of debate. A moment's consideration will make apparent the fact that the disintegration of some iron structures does not belong to this category. To begin with iron ships, for example, the Megæra calamity was not needed to impress the fact that on the oxidation or non-oxidation, the integrity or degeneration of a few square inches of an iron plate, the whole question of the safety or the perdition of a ship's crew turns. Take again, the case of tubular bridge constructions and iron suspension bridges, of which the two structures across the Menai Straits are prominent examples. Here it will be evident, on consideration, although the thought is alarmingly disquieting, that day by day they grow weaker, and that no means of effecting repairs, wholly reliable and satisfactory, are known to exist. Granting —and the postulate is not logically to be evaded—that the inferior limit of cohesion is slowly but surely approaching, there must come a time when a crash will occur—a catastrophe at the very thought of which the blood curdles. To ignore an inevitable result merely for the cause that reflection is disquieting, is the very reverse of practical common sense. Rather study conditions, making the best of unfavorable actualities, with the intent of providing in future against—more than contingencies—*certainties*, by the utilization of such aids as science has put within reach. For reasons that will be obvious without specifying them, we regard the preservation of iron ships as of less pressing import than that of suspension and tubular bridges. Whether a ship be of wood or of iron, its normal or calculated life is not great. Some 50 years, perhaps, may be fairly considered as a long term of existence. The times of possible calamity to a ship are comparatively short, viz., only from port to port ; moreover, even though an iron bottom should give way and a leak occur, and further, no means of repairing the disintegration exist, the pumps are still a resource which, as we have seen in the case of the Megæra, may fairly be relied on to tide over the utter catastrophe of sinking and utter destruction. To our mind, the actuality of iron bridges, tubular and suspension, is far more serious. Whereas a ship is designed and constructed to last only a *short* time, a bridge, comparatively so to speak, is meant for *all* time. It behooves the engineer, then, to ponder well the elemental deteriorating forces which act upon the material of their construction. Chemically regarded, the relations of iron to external influences are not difficult to enunciate. This metal may be taken, for purposes of investigation, as presenting itself in the three states of actually pure iron, of impure though still malleable iron, and of cast iron, which latter, chemically speaking, is the metal in its major degree of impurity. For practical purposes, we may eliminate the first. Absolutely pure iron is a mere chemical curiosity, never occurring in practice, and not often met with in chemical laboratories of research. Ordinary wrought iron—

which is the metal in its highest state of practical purity—and cast iron, are the only forms with which we have to concern ourselves in any investigations relative to protecting the metal against external agencies. Now the fact may be taken as proved, that if iron be absolutely protected against external agencies, it is, chemically speaking, indestructible. We concede that though one of many circumstances, prolonged vibration being of the number, iron may assume a new molecular state, a state more or less crystalline, in point of fact, whereby its cohesion is weakened. Fortunately, however, this result in practice is found to be rare, more rare, indeed, than either theory or laboratory experiments would seem to promise. Whether rare or frequent, the condition is one that holds out no hope of amelioration, and hence the engineer must be content to accept it as an integral fault and drawback—a negative quantity in the summation of the qualities of an indispensable metal. To internal, molecular, or mechanical causes of iron weakness, we do not propose to give attention just now, only summarizing the chemical conditions which affect iron externally. What engineering practice requires is some material which, superimposed upon iron, wrought or cast, shall screen it from the elements, for all time if possible. Now in supplying an indication or hint, an iron casting, if thoroughly studied, is expressive. The circumstance must have come home to the apprehension of every observant engineer that an iron casting if taken from the mould, and neither filed nor otherwise abraded, may be exposed to air and moisture for long periods with hardly any effect. If filed, however, planed, or otherwise disintegrated, then it is found that on the parts so meddled with, the elements work corrosion proportionate to their kind and their degree of concentration. Pursuing investigation, it will be found that the immunity depends upon a superficial glaze, readily discriminated as the silicate of iron. This casualty points to the artificial use of some sort of silica glaze for the preservation of iron surfaces both wrought and cast; but, unfortunately, except in very rare instances, the artificial use of any such silica glaze is impossible. Many attempts to employ silica have been made, using this material in the condition of soluble glass. These experiments have been invariably unsuccessful, and for very sufficient reasons. Except the silica glaze could be laid on by some igneous process, the probabilities of duration would be against it. The very circumstance of the glass being soluble affords a strong presumptive reason that it, under natural conditions, should in the end wash away. Accordingly we have never seen any sort of artificial silica glaze which fulfils the indication desired, and we have no belief that further experiments in this direction will accomplish what past experiments have failed to achieve.

Before further investigating the qualities of other iron surface coverings, it will be well to pass under consideration the merits of the so-called galvanizing process, otherwise the covering of a surface of iron with a thin surface of zinc. This process is known to be very efficient up to a certain point when applicable, but a zinc covering, however thick, will not protect iron in perpetuity, as is sometimes erroneously imagined. The science of zinc covering is very ill apprehended, though its principles and practice can be easily set forth. It is a law that when two metals come in contact, one of which is more easily acted upon than the other, the metal of naturally lesser destructibility is wholly protected so long as a competent amount of the other metal remains to be sacrificed. The result will wholly depend on the nature of the metals used. If the metallic couple be lead and iron, then it is the latter which suffers, as we find when iron street palings are fitted to their sockets with lead. The pairing of copper with iron is still more destructive to the iron, hence the well-known impossibility of copper sheathing the bottom of an iron ship. Tin and iron constitute another metallic couple in which iron is the metal sacrificed, as we constantly see in the example of tin plate. Here, so long as the tin surface actually remains intact, of course the underlying iron is hermetically sealed, and no chemical effect can happen ; but so soon as the tin is disintegrated, exposing the iron, then the latter perishes much faster than had there been no tin at all. The coupling of zinc with iron so completely reverses voltaic conditions that the zinc alone suffers, and even when the zinc is all oxidized the resulting oxide constitutes a mechanical protection of no small efficiency. The so-called galvanization of iron, then, although efficient up to a certain point when applicable, is under so great a variety of circumstances inapplicable, that a competent and generally available mode of protection has still to be sought. In the investigation of this we come to the divers category of paints, by whatever name designated. These have to be considered in reference to the two points of vehicle and pigment, both of which have to be taken count of. Amongst the most frequent of pigments is lead oxide in one of its many varieties, but we venture to affirm that no one pigmentary matter for iron surfaces can have so many powerful objections alleged against it from the side of theory, or a heavier inculpation from the records of practice. As a supposed protection to the bottom of iron ships, lead oxide least well responds to the result intended. The fact has been conclusively proved that, under the condition of immersion in sea water, lead oxide paint laid upon an iron surface is prone to be decomposed, and to evolve metallic lead, the effect of which has already been illustrated by the case of iron palings lead socketed. If experience be appealed to, as results have proved, there can be nothing more clearly indicated than the utter abandonment of lead oxide as a pigment for this class of work, no matter what the vehicle of incorporation may be. As a pigment or body color for iron surfaces, we believe that oxide of iron is, if not the best, the best available ; but, as will presently be seen, we lean to the opinion that the very best protective paint, if paint it may be called, for the protection of iron, is marine glue, dissolved in the curious fluid cupro-ammonium. It may be either used alone or in combination with a certain percentage of white arsenic. This semi-fluid never blisters, not even when laid on hot surfaces; it dries in half an hour, and, so far as theory furnishes indication of futurity, it should be imperishable. There are some to whom the very sound of copper in connection with iron will come as an evil omen, but the alarm is misplaced. Whether a copper solution shall destroy iron or protect it, will depend wholly on the nature of the copper solution. For example, a solution of ordinary blue vitriol, or sulphate of copper, acts so rapidly on iron, that it may be even used instead of aquafortis for etching on iron or steel plate ; but as for cupro-ammonium, a bright steel or iron surface, if immersed in this, *never rusts or otherwise tarnishes* so that a cupro-ammonium bath would perhaps be the best means known of protecting from rust delicate steel goods, such as surgical instruments.

Having treated thus much of the means of protecting iron surfaces from ravages of the elements, it may be well to particularize as to what those changes are. Oxidation is commonly but erroneously spoken of as though it were the only agent promoting the destruction of iron. This is so far from being the case, that both chlorine and sulphurous acid are far more disintegrating. Chlorine, however, so seldom is developed in air, that practically it may be left out of account ; though as to ships' bottoms, the chlorine of chlorides in sea water has a wide sphere of practical destruction. Far otherwise is the case with regard to sulphurous acid, a gas which, associated with moisture, as it is, in railway tunnels, wreaks sad damage on all iron structures exposed to its influence. It may be well to remark also that, wherever sulphurous acid exists in any considerable quantity, the zinc surface of galvanized iron is no protection, the former metal undergoing solution so fast, when coming into contact with sulphurous acid and moisture, that *washing away bodily* is the fittest expression indicative of what happens under these circumstances.

A COMPENSATING COMPASS.

From "Engineering."

M. Arson, engineer to the Parisian Gas Company, has just invented a compensating apparatus for correcting the deviation of the compass. The needle of course does not in general indicate the position of the magnetic north. It is affected by the masses of iron entering into the construction, the armament, or the cargo of a ship. These deviations, which were very feeble in the time of wooden sailing vessels, have become more and more considerable, in proportion as iron has been more largely used in the hulls of ships, as powerful engines and boilers have been introduced, as iron armor plates of ever-increasing thickness have been added to the sides of vessels, and as iron has been utilized for masts and rigging. There are cases where the magnetic influence of the ship so overbalances that of the earth, that although the position of the compass is chosen with the greatest care, it is impossible to obtain much information from its indications.

The means most generally employed to escape this inconvenience consist in checking the deviation of the needle by the influence of the ship, and preparing either tables of corrections or a curve, called Napier's curve, the inspection of which allows the deduction of the true from the observed variations. This estimation of deviation entails a rather long and delicate operation, which, moreover, has to be repeated for different latitudes, to allow for the alterations of magnetic influence.

The mathematical works of Poisson and of Airy have furnished, it is true, analyses of complicated magnetic phenomena, and many investigators have proposed means of compensating the deviating influences. But navigators have shown in general little confidence in these various systems, because all would require frequent changes in the position of the magnets, or of the masses of iron which serve for compensation; and these changes involve operations so delicate, and an incertitude so great, that it is preferred to put confidence in a compass which is supposed to be compensated, and which is more or less true.

The masses of iron in a ship act in two ways on the needle of the compass: first by their permanent magnetism, and then by the induced magnetism that they take under the influence of the earth. The first effect is constant, and comparatively easy to subdue. The second varies with the position of the ship, and can be compensated only by a movable needle.

The uncertainty of the moving compensators involves, in the port of departure, the correction of the deviation of the compass by a magnet as far as possible, then ascertaining by direct observations the remaining deviations, in order to place their quantity on the table or on the curves of correction. At present this is the general practice in the navy.

M. Arson hopes by his arrangement to obtain exact compensation. Fixed magnets compensate the deviations due to the permanent magnetism. Bundles of soft iron wire placed according to certain laws given by calculations, ought to compensate the deviations caused by induced magnetism in all positions of the ship and in all latitudes. The proposed apparatus, which has already been applied on one of the steamers of the Transatlantic Company, contains, besides the ordinary card, a second card, serving as an indicator. When it is wished to follow a given route, this latter card is traced by means of a wheel until it indicates the desired angle. Now by this movement the operator has placed the packets of soft iron into the position in which they are required to compensate for the deviation corresponding to the position of the ship. It is sufficient, then, to adjust the needle of the compass to the same angle which has been given, in order that the route indicated may be actually followed.

Conversely, if it be wished to ascertain at any moment the route which the ship follows, it can be done by moving the wheel before mentioned until the repeating circle indicates the same angle as the compass. By this movement the compensating parts will have been placed in the position which corresponds to the compensation in the azimuth where the vessel is; the angle observed will be the true angle of the route.

If the results sought can be obtained, they will be obviously invaluable. Seamen experienced in these difficult questions will be the best judges of the apparatus of M. Arson.

For the fabrication of an article called sponge paper, lately patented in France, evenly and finely divided sponge is added to ordinary paper pulp, and this is worked, as in the common paper making apparatus, into sheets of different thicknesses. It is said to have all the peculiarities of sponge, absorbing water readily, and remaining moist a long time. It has been used as dressing for wounds with considerable advantage, and is capable of several important technical applications.

ROYAL INSTITUTE OF BRITISH ARCHITECTS.*

THE BRIDGES OF LONDON.

After treating of the bridges of London historically, as connected with the varying circumstances of the metropolis in early and later times, the author proceeded to notice them simply as means of communication considered with reference to the localities on each side of the river, and to traffic as developed by increased population and trade. On this head he referred to the great difficulty now experienced on account of the great accumulation of business at theEast-end, considered in connection with the very large traffic on the river up to London Bridge. The two great traffics by land and water, as it were, overlap. Bridge communication, he pointed out, is much wanted in the neighborhood of the Tower ; the great river traffic, however, will not admit of interference below London Bridge, except at enormous cost. High level bridges have been proposed, a tunnel has been constructed, but still the traffic from the east of London Bridge comes to that crowded thoroughfare, and there is no immediate prospect of any change in that respect. Much has been said of late years as to the widening of London Bridge, but the difficulty was not so much on the bridge itself as in the approaches; the object should therefore be to divert traffic westward as much as possible. If it be determined to widen London Bridge, it should be done so as not on any account to interfere with the general elevation ; any addition by ironwork would be a barbarous proceeding, destroying the effect of one of the finest bridges in Europe ; besides, such addition to the bridge would not relieve its approaches, which are as objectionably crowded as the bridge itself ; moreover, as the foundations of the bridge would not admit of more weight being put upon them, this would be fatal to several plans which have been proposed. One suggestion for widening London Bridge, which has been for some time before the Bridge House Estates Committee, was shown by two plaster models exhibited by Mr. Carr; the proposal consists in thrusting the granite parapet somewhat over on to the cornices and to make it as thin as granite will admit of being worked and fixed in safety. The footpaths are now 9 ft. wide; the addition would be 2 ft. 6 in. on each side of the bridge, making the footpaths 11 ft. 6 in. wide. This plan Mr. Carr considered as the utmost that should be attempted. The great object, however, should be to lead the traffic westward to Southwark Bridge. The toll is now abolished, and Queen Victoria street on the one side and Southwark street on the other have opened up good approaches to that bridge; but great hindrances to its more extended usefulness are its steep approach and narrow width. To render this bridge capable of taking its due share of traffic, it is proposed to take down the existing cast iron arches, and to substitute arches of wrought iron; by this change of construction the thickness of arch and road material might be reduced from 9 ft. to 5 ft. 6 in. It is proposed also to reduce the headway underneath from 29 ft. 6 in. Trinity high water to 25 ft., making it the same as at the new Blackfriars Bridge. The summit level of the roadway would thus be lowered 8 ft., which would admit of the gradient on the south side being altered from 1 in 26 to 1 in 43, and on the north approach from 1 in 20 to 1 in 40—1 in 40 being the standard of good gradient fixed by the Bridge House Estates Committee for the new Blackfriars Bridge. In altering the arches it is proposed to corbel out the footpaths, increasing the width of the bridge from 42 ft. to 54 ft., thus making it the same as the present London Bridge. The nearest route from the Bank to the Elephant and Castle is over Southwark Bridge; if, therefore, the approaches were made good and the width of the bridge increased, it is felt that a considerable portion of the traffic now using London Bridge might be drawn westward to Southwark Bridge. Waterloo Bridge should be thrown open toll free, but there is very little prospect of this being done at present. The rebuilding of Westminster Bridge of a width of 84 ft. has provided ample accommodation there. It may be regretted, Mr. Carr thinks, that the inclination on this bridge itself has not been made a little steeper, in order

* A paper read before the Royal Institute of British Architects, by H. Carr, C. E.

to ease the approaches; the gradient on the bridge itself is 1 in 58, and the approaches 1 in 30 at the steepest part, whereas a general inclination of 1 in 43 would have been more advantageous for the road traffic, without interfering to any appreciable extent with the river traffic. The approaches have been somewhat sacrificed to the bridge, instead of the architect considering the whole as one work, and giving the best possible inclination throughout. Lambeth Bridge was built to meet a supposed want, but, singularly, little traffic passes over it. Vauxhall Bridge is in a good position, but the extension of the South Western Railway from Vauxhall to Waterloo Bridge, and lately the formation of the Southern embankment from Vauxhall to Westminster Bridge, have caused a very severe loss to the Company. Chelsea Suspension Bridge is a valuable means of communication for residents in the adjoining localities, and though it cannot be said to take any part in the great metropolitan traffic as yet, still, as building increases, free access to Battersea Park becomes more and more desirable.

Mr. Carr next proceeded to consider the bridges of London as mechanical structures, with reference solely to strength and stability. Beginning with the foundations, he said that the original timber bridges built by the Saxons and Normans across the Thames at London seemed to furnish examples of the importance of driving the piles of such bridges deeper than was then accomplished, for they were easily washed up by floods. The defect of these piles probably led the builders of the first stone bridge into the opposite extreme —viz., making the piles too massive, and by their very mass leading to destruction by increased scour. The piles of the first wooden bridges were not stable; the foundations of old London Bridge were not altogether successful; therefore in building the next bridge (Westminster) another plan was tried, the French system of caissons; in fact, barges in which the piers were partly built while floating, then sunk in place and the sides removed, the site being dredged to receive them. The objections to this plan, are that a perfectly level bed cannot be obtained, and the caisson bottom must inevitably rest in the first instance on limited portions. Increased weight and time will no doubt produce a more even bearing, but it must involve settlement to some extent. The caisson system was adopted at the next bridge built, Blackfriars; the caissons bottoms or platforms on which the piers stood, lately taken up, were 88 ft. by 37 ft., and 2½ balles thick, area 3,256 ft., bearing a weight of 11,241 tons, or 3½ tons per foot super, supposing the whole area to take its share of load equally; but in fact the weight was carried by a much more limited area. The load per foot on the surface of timber area of footing was about 6 tons. Had this weight been evenly distributed over the whole bearing surface, the surface being the London clay or gravel, resting on the clay, the foundation might have been good enough as long as not undermined; but there were symptoms of the arches having yielded on the centres being struck, which leads to the suspicion that the pier foundations had slightly moved, in fact, had come to their bearing as the increased weight came on. In arches Nos. 5, 6, and 7 from the south, lead was found run into joints on the north side, in each case the arches evidently having lurched over to the south, opening the joints on the north haunch. Lead was run in as much as an inch thick at extrados, tapering inwards, the masonry joint being tight at intrados. The opened joints were not in one course through, but stepped a course up or down. It is supposed that some 4 or 5 tons of lead were taken out, but the greater part was stolen. This system of caissons is now universally admitted to be defective and inefficient, principally from liability to be undermined by increased scour. Waterloo Bridge was the first of the bridges built in what may be called the present day—built after the date when engineering had become a distinct profession. The foundations of this bridge were of a totally different character from all preceding ; no pains or expense were spared, and everything was done which at the time was considered most efficient. Coffer-dams of double piling and puddle were formed, which did their work most successfully, the foundation being laid dry. Southwark Bridge followed on the same principle, and new London Bridge immediately after. Taking the case of London Bridge, the area of the pier foundations was laid dry, with coffer-dams, 43 ft. below Trinity high water ; bearing piles of whole balk were then driven over the whole space 4 ft. and 3 ft. 6 in. apart, cross sills were laid on the pile heads, the intervening spaces were filled in with rubble and brickwork, the whole planked over, and the piers built on the foundation thus prepared. The weight on the foundation of central pier is about 21,151 tons ; supposing this to be evenly distributed over the whole of the bearing piles, there would be a weight of about 88 tons on each pile, and of course, on each sill crossing each pilehead. The specification describes these sills as either elm or fir. In new Westminster Bridge another plan of foundation was adopted, resembling that in building old London Bridge, the object in view being to avoid the expense of coffer-dams. The principal bearing is on 145 elm piles in each pier driven 3 ft. 3 in. and 2. ft. 6 in. centre to centre, and cut off below low water. These elm piles are surrounded with 44 iron piles, 5 ft. from centre to centre, with cast-iron plates driven between the piles, thus forming a complete casing which surrounds and includes the elm bearing piles ; the interstices are filled in with concrete, making the whole solid. The weight on these piers is so slight when compared with that on the piers of London Bridge that the question of foundation becomes of less moment. The weight per pile is about 15 tons, supposing the elm piles to carry the whole weight, or about 11½ tons, supposing the iron piles to take their share. Query, would not solid cement concrete resting on a well-prepared bed have made a more efficient and more durable foundation than piles of timber, the insterstices only filled in with concrete? Homogeneity is the essence of strength ; one homogeneous mass is the true foundation wherever it can be obtained. The next system of foundation introduced was that of iron cylinders open at the bottom and sunk into the bed of the river by excavating inside first by divers ; afterwards, when water-tight strata are reached, by pumping out and working dry, the interior, when a sufficient depth has been reached, being filled solid with concrete or brickwork. The railway bridges at Charing-cross, Blackfriars, and Cannon street are thus carried. Nothing can exceed the facility of putting down such cylinder foundations, and nothing can be better where sufficient area is given, and where such form is suitable to the superstructure. The weight required to sink these cylinders seems to be about 3 tons per ft. of circumference, that weight including the cylinder itself and the load placed on it for driving it down. There is one very important distinction between railway and road bridges. In railway bridges the weight is always carried in the same position, and is naturally transferred on to definite and distinct points ; circular cylinders placed under these terminal points of the arch or girder become, therefore, suitable foundations. But the case of a road bridge is different, inasmuch as the varying traffic is distributed indiscriminately all over ; the weight and strength of the bridge have, therefore, to be distributed also over the whole width, and consequently a continuous pier is more suitable than such isolated columns as are sufficient for railway bridges.

Having given various interesting details of the rebuilding of Blackfriars Bridge, Mr. Carr said that in the upper portion of the piers of bridges there is not such scope for variety as in the construction of foundations. For the Thames, the right material, no doubt, is granite, and the best hearting is good sound brickwork. Good sound brickwork carefully built in Portland cement or lias lime is stronger work and more solid than even ashlar throughout ; but the granite facing must be well bonded in, not such work as is sometimes done—a face carried up of stone nearly of the same depth throughout. The arches of all bridges of any size or importance, up to a late date, were always of masonry; but after various examples of iron had succeeded elsewhere, cast iron was used for the arches of Southwark Bridge. In later times the manufacture of wrought iron has advanced so rapidly, and wrought iron offers such advantages over cast, that it is now almost universally used. The cast-iron arches of Southwark Bridge certainly are a bold and noble construction. It is a singular and almost unique fact with regard to cast-iron arches, that they were in the first instance made much slighter than in later works. The bridge at Sunderland, of 236 ft. span, has arches of about 46 in. area of metal. Southwark Bridge centre arch of 240 ft. span has arches of 6 ft. depth, and 122 in. area. The tendency in all other works has been to give greater mass in the first instance, and to build slighter in later times. The builders, however, of Sunderland Bridge gave their successors no opportunity of paring down; the margin of stability there was small indeed. The danger with cast iron in general, and cast-iron arches in particular, is that of getting an unequal bearing either from defective fitting, or from expansion and contraction. The rise and fall of Southwark Bridge arches is about 1 in. for ordinary change of temperature, or about 1-40th in. for each degree, such rise and fall must produce considerable variation in the load to be sustained by the extrados and intrados of the arches. The brittleness of cast iron, together with the improved facilities for the manufacture of wrought iron, have led to the almost univeral adoption of wrought iron for arches. If one portion of a wrought-iron arch, say the intrados, should from bad workmanship or other cause have more load to carry than the strength of the metal will bear, a general compression would take place in that portion, and a corresponding shortening, allowing the remainder of the arch (the extrados) to come into play before any mischief took place. Though cast iron in the dimensions usually experimented upon has probably double the power of resisting compression that wrought iron has, nevertheless it is usual not to trust to it with much more than about half the load, showing how strong is the general feeling of distrust in that brittle material. As regards oxidation, however, the balance is much in favor of cast iron, both from a less tendency to rust, and also from the same absolute amount of loss being a less percentage on the greater mass. This is a strong reason against using thin wrought plates in any construction exposed to the weather—the loss, say, of $\frac{1}{8}$ in., by oxidation, would be immaterial in a thick casting, but would be fatal in a $\frac{1}{4}$ in. wrought plate. With regard to Blackfriars Bridge, the ordinary course of heating the iron work and dipping in boiled oil was pursued, four coats of paint following. Asphalt paint for the interior surfaces, and Torbay oxide of iron paint, finished with Messrs. Rose & Co.'s olive green, for the exposed face. The great desideratum of the day, no doubt, is some means of permanently protecting iron from rust; this is now said to be done by Messrs. Turner & Allen, of Upper Thames street; their process is to coat the iron with bronze or copper in such a manner as to effect perfect union between the two metals; if this union of the two metals really be as perfect as stated, no doubt it will prove a most valuable discovery. Having given various interesting details of the strength of materials used in the new Blackfriars Bridge, and described the temporary wooden bridge at Blackfriars, Mr. Carr, in conclusion, treated of the bridges of London, considered as works of art.

EXPERIMENTAL TRIP OF THE INDIAN GOVERNMENT STEAM TRAIN ENGINE RAVEE FROM IPSWICH TO EDINBURGH.

By A. CROMPTON.

From "The Engineer."

One of the stipulations in the contract between Mr. Thomson and the Indian Government, when the former tendered for the supply of 4 high-speed road steamers, was that 1 engine at least should, as a test, travel a distance of several hundred miles, drawing behind it a load. The object of this was to learn as much as possible of their behavior when put to severe continuous work.

With this view the first completed engine, the Chenab, was sent by road from Ipswich to Wolverhampton. The results of this trial, though satisfactory as far as the engines proper, and the india-rubber tires, were concerned, were vitiated by the failure of the boiler, which could not be kept steam-tight, and otherwise gave endless trouble. On the completion of the second engine, the Ravee, the field boiler of which gave excellent results when put through a series of trials with wood fuel on Ipswich Race course, Mr. Thomson, before giving his final consent to the adoption of the same boiler in the remaining 3 engines, desired me to put it through as exhaustive a trial as that undergone by the Chenab, in order that we might find out the weak points, if any, of the Field system, and furthermore note the effect of continuous high speed on the engines and rubber tires, this high speed having been unattainable with the defective boiler of the Chenab. As the Indian Government had been very urgent for the speedy dispatch of the engines, no time could be wasted in further preliminary trials. The engine and omnibus were ordered to be packed and ready for an early start on the morning of September 13th. In order to save repetition I will give a brief description of the Ravee. She weighs when loaded with 1 ton of coal and 375 gallons of water in the tank about 14 tons ; driving wheels 6 ft. diameter, cylinders 8 in. diameter, 10 in. stroke, geared, fast speed $3\frac{3}{4}$—1 ; slow speed, 12—1 ; revolutions of crank shaft at 10 miles an hour, 157 ; boiler has 50 sq. ft. of heating surface in the fire-box, and 127 sq. ft. in the Field tubes ; grate surface, 11.25 sq. ft. As this large grate surface is especially intended for burning wood, we contracted it to 7.6 sq. ft. by building a ring of fire-brick round the grate. The boiler contains 13 cwt. of water. The omnibus when loaded with tools, luggage, etc., varied from 5 to 6 tons accordingly as coals and the engine shoes were carried in it or not. The gross load, therefore, averaged during the whole journey from Ipswich to Edinburgh a little over 19 tons. Our staff consisted of one fitter, one driver who was a lad of seventeen, one fireman, and myself.

We left Messrs. Ransomes, Sims, and Head's yard in Ipswich at 3.40 A.M. on Friday, September 15th. The road being good and sound, we rattled along at a good pace, and reached Stowmarket at 5. 30, and filled up with water—or rather didn't—as the town pump would only supply us with 250 gallons. This necessitated a stop for water at Woolpit, 8 miles further on. We reached Bury St. Edmunds at 8.15, having run the first 26 miles in $4\frac{1}{2}$ hours including all stoppages for pumping, etc. After getting photographed, having coaled and breakfasted, we started at 10.30. The road was loose and heavy all the way to Newmarket, and the water was very difficult to get. We arrived at Newmarket at 1.27, and found that the waterworks people could not give us a single pailful, as they had not enough to water the streets. The landlord of the Golden Lion, however, came forward, and offered to us in our need the contents of the cistern in his back yard. As the entrance to this yard was too low and narrow to admit the engine, we were obliged to stand out in the main street, and carry the water in buckets, as our hose was not long enough to pump it in direct. Carrying water in buckets is not an intellectual pursuit, and nothing could induce the tight-trousered race-course-haunting inhabitants to lend us a hand, so we had to do it ourselves, and were consequently not in the best of humors when the chief policeman came and told us to "move on." It was too much. I mildly replied, "Mr. Policeman, under the circumstances 'moving on' is impossible ; but if you will kindly 'run us in' to that much desired back yard, I will forward a good report of your engineering capabilities to the bench of magistrates."

We left Newmarket at 2.40, and arrived at Ely at 6.15. The whole of this road was so heavy that the engine was literally ploughing along in 3 in. or 4 in. of loose dust and flints. We had a very narrow and steep iron bridge to cross as we entered Ely ; it barely admitted the engine, 8 ft. 6 in. over all, between its parapet walls. We coaled at Ely, and got a guide for Peterborough—such a designing ruffian! his sole mission appeared to be to guide us into scrapes. Our troubles commenced about 10 miles after leaving Ely. Our guide piloted us into a *cul de sac*, terminating in a triangular piece of ground, as boggy and treacherous as you please. As its greatest diameter was about 30 ft., it required some manœuvring to twist the train round and come out again. A few miles further on we crossed a very indifferent wooden bridge. The wooden bridges in the Fens are most of them built on this plan :—The piers are of piles, and the roadway is laid on 14 in. square oak balks, untrussed in any way. Where the spans are short, this is all very well, but when they get to 18 ft. and 20 ft., as is the case with some of the bridges near Peterborough, traction engines had better go round. However, Meeple Bridge was judged to be safe. Shortly after crossing it, and a second one over the Forty Foot river, our guide insisted upon our turning sharp round to the left, and taking the road along the top of the bank of the Forty Foot. This road was tolerably wide at first, but gradually narrowed until it was only about 10 ft. at the top, with a steep slope on one side to the river, on the other to the Fen ditch. The surface consisted of a thin coating of metal laid on the springy Fen soil of the bank, and the whole rose and fell under the engine like the waves of the sea. It was an anxious time for the steersman, as he had only a margin of a few inches outside each driving wheel, and if he came within this margin ever so little the side of the bank immediately began to cut and slide away under the wheel. We had 10 miles of this fearful road, but to the honor of the rubber tire, be it said, it never once failed us in a situation where a slip or failure to bite for one single instant would have been a very serious matter. To add to our other troubles, we found that the water of the Forty Foot river was brackish, being admitted from the sea to flush the siphons. Our boiler did not like this at all, and threw it out almost as fast as we put it in. Within a mile of the end of this piece of road a Field tube burst. It acted like a fusible plug and put the fire out immediately. We lay down in the 'bus for a few hours' rest, in order to give the boiler time to get cool. This was about 2 A.M. We had run 69 miles from Ipswich ; 12 hours 9 min. travelling, 11 hours 51 min. for halts and meals ; speed, 5.67 miles an hour ; consumption of water 21.7 lbs. per ton per mile; consumption of coal, 5.6 lbs.; number of lbs. of water evaporated by 1 lb. of coal, 3.85. This day's performance stands alone, as will be seen hereafter, in the enormous quantity of water used, the heavy consumption of fuel, and the low evaporation The first might have been expected on account of the continuous heavy road the whole way from Bury St. Edmunds, and the priming during the last 12 miles, caused by the sea water; but the two last are still a mystery to me. It must be recollected that we had never burnt any coal in the boiler before this day's trip, and were consequently in the dark as to proportion of fire-grate surface and blast required. The engine has still her wood burning fire-bars, and a great deal of fuel is wasted by dropping through them. However, this will not account for the great difference between this performance and that of the ensuing days.

After resting we replaced the burst tube and got up steam. This took about 3 hours. The tube had opened for about an inch near the end, apparently in consequence of defective welding. We started at 12.30, and arriving at Ramsey we were told that the bridge at Whittlesea bore a very doubtful character. After some delay we found out that if we avoided Peterborough altogether we could get on to the great North-road at Sawtry without making any very considerable detour. After 12 miles of cross country lanes we reached the much desired road, and found such a change in the rolling resistance! The engine appeared to leap forward directly we got on to its hard level surface. Here we took off the shoes and stowed them away in the 'bus, otherwise, redistributing the weights, making the engine weigh about 13 tons 10 cwt., and the 'bus 6 tons 12 cwt. Along the great North-road we made capital way, running the 17 miles between Sawtry and Wansford-in-England under 2 hours. Arrived at Wansford we were most hospitably received by Mr. Jackson of Stebbington House, who insisted upon our putting up the engine in his grounds and entertaining us over the Sunday. The result of this second day's run showed an improvement on the first, particularly in the evaporation, which rose to 4.96 lbs. of water per lb. of coal. The average speed was 6.8 miles; consumption of water, 16.1 lbs. per ton per mile; consumption of coal, 3.25 lbs. per ton per mile.

On Monday morning we started at 6 A.M., reached Stamford, 6 miles, in 35 min.; Grantham, 26 miles, at 11.15 A. M. After breakfasting and watering, we ran to Newark, 15 miles, in 1 hour 40 min. We ran most of the way at the rate of a mile in 4 to 6 min., according as the ground was level or undulating. We should easily have averaged 12 miles an hour, but for the frequent stoppages for horses, the slow speed through villages, etc. We arrived at Retford, 6.55; Bawtry, 10.45; Doncaster, 11.30; and laid up the engine for the night in the Wool Market. We had run 83½ miles in 10 hours 25 min. of travelling, 7 hours 31 min. for meals and pumping water—speed 8 miles an hour. The only noticeable thing to-day was the ease with which the engines worked, the small horse-power required, and consequent economy of fuel—much of this last due, no doubt, to the excellence of the road.

A serious defect showed itself in the rubber tire of the steering wheel during this day's run, which afterwards necessitated its removal. On submitting this tire to the examination of the rubber manufacturers, the only cause which could be assigned for its failure was imperfect, or rather insufficient vulcanization.

The following morning we left Doncaster at 9.7 A. M., and arrived at Boroughbridge, 42 miles, at 7.55 P. M. At this place the defective tire was removed, and wooden felloes, hooped with iron tires, substituted. This made the steering wheel a rigid one, and its use an interesting experiment. But a few miles showed that, although the steering-fork is carried on steel springs, nothing over the speed of 5 miles an hour could be attempted without fearful jolting and fracture of the steersman's teeth. The remainder of the journey to Azerley Hall, near Ripon, was accomplished in a couple of hours; the result of the run from Doncaster being as follows :—Speed, 5.6 per hour; consumption of water 16.28 lbs. per ton per mile ; consumption of coal, 3.00 lbs. per ton per mile; pounds of water evaporated by pound of coal, 5.37. Part of the road between Doncaster and Tadcaster was very hilly, the last few miles to Azerley Hall a mere country lane. At Azerley we had to wait two or three days for the spare tire, and when we had got it were detained weather-bound for several days longer. Your readers will recollect the exceptionally heavy rainfall of the last week in September. Seeing no chance of the weather clearing, we put on the shoes, and started from Azerley at 8 o'clock on Monday morning, the 2d of October. We found the road so much better at Ripon that we removed the shoes again, and made a rapid and economical run to Darlington, 40 miles from Azerley. Although the road was wet and slippery, it was free from greasy mud, and we were able to get along without the shoes. The results of the run this day, without shoes, were as follows:—Speed, 8.5 miles an hour; consumption of water, 13.1 lbs. per ton per mile ; consumption of fuel, 2.36 lbs. per ton per mile ; evaporation, 5.70 lbs. This is about the best performance made by the Ravee when burning coal. We left Darlington the following morning at 8.45. Just after passing Ferryhill, at 12.35, we found that one of the connecting rods was bent; we took it out and straightened it; this occupied 7 hours. We got under way again, and arrived at Durham at 9 P. M. We found some of the paved streets of Durham presented the steepest gradients of any we had hitherto met with, and felicitated ourselves on having put on the shoes at Darlington. Arrived at High Level Bridge End, Newcastle, at 3.10, and were refused leave to go over. The man in charge said nothing over 7 tons had been allowed, so we had to turn round about and go down to the Low Level Bridge, and then up the steep and greasy gradients of Dean street, which we ascended at the speed of 6 miles an hour, although I should think the gradient is 1—13. Coaled at Seaton Bourne Colliery, at the very pit mouth, and reached Morpeth at 10.40. After breakfasting, and coaling, we set out across the bleak moorland road to Wooler, and not often before, I suppose, was such a road traversed by a traction engine. The road is one series of ascending and descending inclines, most of them long and steep. Outside Wooler we had an amusing passage of arms with the tollgate man, who deliberately refused to open his gate. The head lamp was removed, and the flange of the framing of the engine placed gently against the gate; it was wonderful to see how easily the gate opened, without a murmur, I should say —and the tollman's face! At Wooler, at 11.45, we were refused admittance at the miserable little inn, because we were so dirty that the landlady was "sure we should dirty the sheets so much that the commercial gentlemen would not like to use them after us." The men got shelter somehow, and I improvised a shake-down out of the 'bus cushions. The coal, although only 3 or 4 miles from the pit mouth, is here sold in bowls, holding about 100 lbs. each, at something over 1s. a bowl. If the gentleman in "Punch" in search of quiet were to go to Wooler I think he would find it.

The results of this run of 78 miles were, speed 4.05 miles an hour. This was on account of the constant gradients, the frequent stoppages for horses near Durham and Morpeth, and the continuous rain. Almost all the streams were in flood, and the water taken very muddy. Consumption of water, 17.9 lbs. per ton per mile; consumption of fuel per ton per mile, 3.70; evaporation 5.01. We were 19 hours 15 min. travelling, and 20 hours 15 min. halting. The following morning, October 5th, we started at 8.30 A.M., and arrived at Cornhill Railway station, near Coldstream, at 10.50. Here, whilst standing to take in coal, occurred almost the only accident from horses that happened during the whole trip. A string of carts laden with lime was passing the engine, which was drawn to one side of the road; two or three of the horses got frightened, and capsized their carts against a wall; luckily, no one was hurt, nor were the carts broken. The hinds were very sulky at having to shovel all the lime into the carts again. Passed through Kelso at 3.55, and had a considerable bother under the Duke of Roxburghe's wall at Floor's Castle. The Duke's wall is high, and does not allow the wind to dry the road; consequently, all along under the wall there is a coating of green, slimy soil, which is not favorable for traction engines. As we, poor innocents, were journeying along in this stuff, we had to draw up and wait some little time to allow some carriages returning from the races to pass. On starting again we found we had settled into a mess of butter, and it was only by scheming and scraping the road, and using Mr. Aveling's device of always backing out of a difficulty, that we got out. On the top of the hills before reaching Earlston, we had to shorten the shoes, and it was a bitter cold job. I never knew wind to blow so sharply. We halted for a time at Lauder, and made a good run up Lootray Hill, an incline of some 3½ miles in length, and varying from 1 in 25 to 1 in 17, gaining both steam and water as we ascended it. Got breakfast at Blackshields, watered at Dalkeith, entered Edinburgh by the Dalkeith road and the bridges, ran along Princes street to the west end, and laid up the engine and 'bus in Messrs. Drew and Burnett's yard, Fountain Bridge. A couple of days afterwards we took the train out for a trip, for the inspection of Mr. Monteath, the Director General of the Indian Post-office; and on the following Monday, to satisfy that gentleman as to the engine's power of hauling heavy loads up steep inclines, we took her out, with a load of wagons full of lime, to Mr. Bruce's farm, some 27 miles from Edinburgh. In the course of this experiment the engine drew 4 wagons loaded with lime up an incline of 1 in 17, more than a mile in length, being the ascent of the Lammermuir Ridge on the Edinburgh side. As the wagons, with their load, weighed 26 tons 10 cwt., the gross load was over 40 tons, which gives 64 horse power as the dynamometrical horse power. I will, with your permission, give the performances of the engine in a future number in a tabular form.

STEEL MANUFACTURE IN BIRMINGHAM.

From "The Mechanics' Magazine."

The "Premier Steel Works," of Messrs. Cox, Brothers, and Holland, occupy extensive areas in three different parts of the town of Birmingham, namely, Alcester street, River street, and Glover street.

These works, as the name implies, were the first, and are indeed the only, manufactory of steel in Birmingham, and their origin possesses so much intrinsic interest, and is so typical of the great and rapid development of the town generally, that some account of them will be found instructive.

This firm has long been engaged in the production of steel frames for umbrellas, sun-shades, etc., which require steel of peculiar temper and elasticity, uniformity of quality being essential. While their trade was confined within moderate limits, there was but little difficulty in obtaining material of the particular quality required, but as their transactions increased, the demand exceeded the supply. The difficulty grew in almost the exact ratio of the extension of their business; and thus in time became a matter of serious importance, necessitating special arrangements. After many experiments and efforts in various directions, it was finally determined to enter upon the manufacture of the article for themselves, and the result has borne remarkable testimony to the wisdom of this course, for they now not only provide for the large requirements of their own business, but produce steel of every description, which is sent in great quantities to all parts of this country, and exported extensively to every quarter of the globe.

We propose, in this notice, to confine our attention to the system of steel manufacture as practised in these works, reserving for a future occasion an account of the construction of the umbrella frame, which has to pass through 100 pairs of hands and is the result of remarkably delicate and ingenious manipulations; but some idea of the extent of this manufacture may be gathered from the fact that the weekly production falls little short of 50,000 sets of frames.

The composition of steel is still surrounded with mystery, but as we so lately published a paper upon the subject, its consideration here is not necessary.

The iron used for conversion into steel is of Swedish origin, and is received in bars 3 in. wide, $\frac{5}{8}$ths of an in. thick, and about 12 ft. long. These, after being straightened so as to lie evenly, are placed in the converting furnace, which consists of two rectangular vessels, technically called "a pair of pots," made of silicious freestone, capable of enduring great heat without change; in dimensions 12 to 14 ft. long, 3 ft. 6 in. wide, and the same in depth. They are supported upon a depth of 4 ft. of solid masonry, the top course being of firebrick, to prevent settlement, which would crack the pots, admit air, and spoil the conversion. Upon this masonry are constructed transverse or sleeper walls of firebrick, 10 in. thick, and 10 in. apart, upon which the pots rest, the brick divisions forming flues underneath. The pots are placed parallel to each other, but 18 in. apart; the space between them is divided into flues, corresponding with those underneath, extending up the sides and ends of the pots into the firebrick wall which covers the whole. This vault has an arched opening, or manhole, at each end, for charging the pots with iron, or taking out the charge when converted into steel. During conversion they are bricked up and plastered with clay. There is also a small opening over each pot, through which bars can be put. Out of the vault rise 3 chimneys on each side, opening into a large cupola. The fire-grate is under the middle flues and the whole length of the pots, with a strong metal door at each end, kept closely shut, except when being charged. Each pot has a stratum of charcoal evenly laid on the bottom, above which a layer of bars is placed, and covered $\frac{1}{2}$ in. deep with charcoal; bars and charcoal are thus laid alternately until the pot is nearly full, and finished off with a thicker covering of charcoal over the top. The pots, when filled, are covered over with 5 in. of "wheel swarf," which contains iron and steel in minute particles, and, becoming partially fused when hot, perfectly protects the steel underneath from the action of the air. Each furnace has a 5-in. opening through the walls and into the centre of one end of the pots, through which 2 or 3 of the top bars project, the opening being filled up with fine ashes, well rammed, to exclude the air. The fire, gradually raised to great intensity, is kept up for 6 or 8 days. A furnace holds about 16 tons of iron, and is considered to be well worked, if 14 to 16 heats are got out in a year.

When the conversion is supposed to be nearly complete, a top bar is drawn, and, when cold, is broken; its condition shows the state of the whole, and the fire is regulated accordingly. A second or third bar is subsequently drawn, and when the conversion is considered to be complete, the fire is allowed to go out. In 4 days the man-holes are opened to hasten the cooling, and in 4 more the steel, still hot, can be taken out. A full furnace charge is called "a heat of steel," and according to the degree of carbonization required, is called "a spring heat," "a cutler's heat," "a shear heat," "a file heat," or "a melting heat." It should be premised that these terms do not apply to the "temper" of the steel, but to the length of time in furnace.

The bars are now broken and sorted by experienced workmen into the various tempers; the hardest are laid aside for melting, and the softer hammered into shear or spring steel. Those required for shear-steel are broken into lengths of about 1 ft.; are next laid upon each other, 3 or 4 together; then heated in a furnace, to "welding heat," and drawn under the hammer to the size intended. It is then "single shear" steel. If again broken, heated, and hammered, it becomes "double shear" steel, an extra quality used for best table cutlery, and other first-class purposes. Spring steel is made from bars passed at a red heat between grooved rollers until reduced to the particular size required. Shear and spring steel are the chief, if not the only qualities manufactured direct from the converting furnace.

We now come to the important process of cast steel.

The invention of cast steel is assigned to Benjamin Huntsman, who perfected it in 1740, after many experiments, and repeated losses and discouragements. He carefully guarded his secret, and for a long time with success, till it was discovered, as it is said, by a rival manufacturer disguised as a beggar, after which the manufacture soon became general. The melting process is as follows: The steel is broken into small pieces, and put by means of a conical-shaped funnel into a melting pot or crucible holding about 34 lbs., made of a peculiar dark gray clay. Before charging the crucibles they are gently heated to a red heat on an annealing grate, and then placed with covers of the same material upon fireclay stands in the melting furnace, and covered with coke, till furnace and pots are at a white heat. Each furnace holds 24 crucibles. These are kept covered by fresh supplies of coke as required, till the metal is thoroughly melted, which is known by its clear surface and motionless state in the pot. When ready, the crucible is taken by tongs from the furnace, and the steel is poured slowly into moulds prepared for its reception. The moulds can be opened, and the ingots taken out, and removed into the yard to cool, a few minutes after they have been cast. As soon as the pots are empty, the lids are put on and then are replaced in the furnace, a quantity of coke is put in, and the holes are covered. When the coke has burned down so as not to be higher than the pot lids, a fresh charge of steel is put in and the former process is repeated for a second and a third time, after which new pots are necessary.

Heath's process of melting is also adopted to a considerable extent in the works. This consists in cutting the bars into pieces, placing them in the pots with a certain amount of charcoal, and when brought to a melting heat, sufficient manganese is added to make the steel weldable. Steel thus prepared is particularly adaptedfor all purposeswhere soft welding is required. In some instances spigeleisen is also added as a ready vehicle for imparting the manganese.

Tool steel, sheet steel, and steel wire are the chief classes into which cast steel is manufactured.

For tool steel the best ingots are selected. The ends of each being broken to determine its texture and temper, it is heated to a red heat, and drawn under the steam hammer to the sizes required,

For steel wire the ingots are roughly drawn under the hammer into billets, $1\frac{1}{4}$ in. square, and sent to the rolling mill, where they are passed at a red heat between grooved rollers, and reduced at one heating to a $\frac{1}{4}$ of an in. thick, and from 2 ft. run out to 70 ft. long. The rapidity of the rolls is such that, notwithstanding the partial cooling of the steel by lying on the floor, during its passage through the rolls it becomes re-heated from "warm red" to "bright red" by their action. From the last pair of rolls the rods (as they are now called) are coiled upon a drum about 26 in. in diameter, tied in bundles, and passed to the wire mill, where they are subjected to an annealing process, and an acid bath, and are then drawn through steel plates while cold. These operations are repeated from 3 to 5 times, according to the fineness of the wire required. The wire used for the umbrella frame ranges from 13 to 15 wire-gauge numbers. For other purposes any degree of fineness can be obtained.

The process of annealing is as follows. The wire is placed, coiled, in large quantities in a cast iron vessel, actual contact with which is prevented by the insertion of bricks into cast iron ribs. The vessel is closed, and very gradually brought with its contents to a red heat, at which it remains from 12 to 15 hours, when it is as gradually cooled.

To produce sheet steel, large quantities of which are demanded for the steel-pen trade, the ingot is treated as before, but hammered to about $\frac{5}{8}$ths of an in. thick. It is then taken to the rolling mill and passed through flat rollers while at red heat, till it is about 22 wire-gauge. In this state it is suitable for circular saws, and kindred purposes. It is next subjected to the annealing process and acid bath, and then rolled in a cold state till it becomes hard, or, as it is technically called, "dense." The first annealing will permit the steel to be reduced to 30 wire-gauge. The annealing and bathing processes are repeated as often as the steel requires softening and cleaning, till the desired sizes are obtained. This cold-rolled steel is turned to a variety of uses, such as clock and watch springs, children's toys, etc.

Steel has been rolled at these works to a substance but little, if any, thicker than the leaves of this magazine.

NOTES FROM GERMANY.

From "Engineering."

THE HODGSON WIRE TRAMWAYS.

An Hungarian engineer, Mr. T. Bush, has made some improvements on the Hodgson system of wire tramways by employing two parallel cables instead of one. The modified system, it is said, possesses great advantages over the original one, especially with regard to the carrying of heavy loads, and the greater security of the ropes.

METAL FOR BEARINGS.

The following alloy has been found to give highly satisfactory results for plummer blocks, axles, brasses, etc. To 30 parts of melted copper are added 70 parts of antimony; the mixture is melted and run out into thin plates. These are then remelted with tin in the proportion of 90 parts of tin to 10 parts of the copper and antimony, and run out again into thin plates. When used it is remelted, and run into the form required. M. Volk, of Regensburgh, has employed an alloy for many years, of which the following are the component parts: Copper, 5.6 per cent.; antimony, 11.2 per cent.; and tin, 83.2 per cent. He also employs the following mixtures to produce metals for various purposes.

For slide valves:

Copper	81.9	per cent.
Tin	14.8	"
Zinc	3.3	"
	100.0	

or

Copper	67.0	"
Old brass tubes	32.0	"
Tin	10.2	"

For pump barrels, stop-cocks, and valve-boxes:

Copper	87.7	per cent.
Zinc	10.7	"
Tin	1.6	"

For stuffing-boxes, valves, etc.:

Copper	86 2	"
Zinc	3.6	"
Tin	10.3	"

For eccentric rings:

Copper	90	"
Zinc	10	"

For piston rings:

Brass cuttings	94	per cent.
Copper cuttings	6	"

COAST PROTECTION BY TORPEDOES.

Contact and electric torpedoes were both employed for the protection of the German coast during the war. The former had generally a charge of 82 lbs. of powder, and were moored about 3 ft. below the surface of the water. The electric torpedoes were loaded with 220 lbs. of dualin, equivalent to 1,100 lbs. of powder, and were fastened 8 ft. below the water. The explosion of these was brought about by means of batteries placed on the shore, and they were perfectly safe. On the other hand the contact torpedoes were exceedingly dangerous to handle, and three fatal accidents took place in lifting them from their positions. In addition to the defence torpedo, attempts were made to project others beneath the hulls of the hostile vessels, but nothing resulted from this application.

DYNAMITE IN WELL SINKING.

In Denmark dynamite has recently found a novel application, namely, in the sinking of artesian wells. During the autumn of last year, some persons sinking a well at Gjeddesdal struck upon a very hard bed at a depth of 75 ft., which they were quite unable to pierce. As there appeared no choice but to abandon the work, they ultimately determined to try the experiment of a charge of dynamite.

After the bore-hole had been cleared, a bottle containing about 2.2 lbs. of dynamite was lowered. It was attached to two copper wires passed through the stopper of the bottle and insulated by gutta-percha. When the charge was in position, an electric spark brought about the explosion, with the result of a great concussion on the surface, and an upward discharge of the water which stood in the boring.

The hole almost immediately filled with water; giving evidence that the obstruction had been removed, and the source of supply reached.

Two charges were afterwards fired in a similar manner and the sudden rush of water left no doubt about the successful issue of the experiment.

ASBESTOS PISTON-ROD PACKING.

From "The Engineer."

Few engineers who have to do with the steam engine are ignorant of the trouble which is met with in obtaining a really good piston-rod packing. Sound hemp properly "laid up," and copiously lubricated, makes a tight joint enough for a time, especially if the rod is in first rate condition; but the period of tightness is usually short, and the gland requires constant screwing up, and much friction results which is very prejudicial in small engines. If hemp is bad in the case of low-pressure engines, it is infinitely worse when we have to do with high steam, especially if the steam is slightly superheated. A process of slow carbonization appears to go on, the hemp packing loses its elasticity, and becomes nearly useless for its intended purpose. All manner of schemes have been tried to get over the difficulty, combinations of cotton, india-rubber, and wire gauze, such, for example, as Crickmer's patent packing, have hitherto given on the whole the best results. One inventor, indeed, dispenses altogether with cotton and rubber, and uses copper wire gauze alone. In this case the tightness of the joint is no doubt secured by the presence of water and oil lodged in the meshes of the gauze; and we have received very favorable reports from those who have tried this packing. It is still certain that something better than anything hitherto in use is required, and we have a strong belief that this something is supplied by asbestos.

Asbestos is a mineral fibre consisting of silicate of magnesia, silicate of lime, and protoxide of iron and manganese. In mineralogical parlance, it is a fibrous variety of actinolite or tremolite. It exists in vast quantities in the United States, also in the Tyrol, Hungary, Corsica, Greenland, Wales, Cornwall, Banffshire, and in the north and east of Ireland. It is found under various forms, from that of soft silky fibres to that of a hard block capable of taking a polish. As a rule, the lumps or blocks taken from the vein are easily broken up and separated into fibres extremely flexible, and elastic in the sense that each fibre admits of great extension in the direction of its length without contracting again, greasy to the touch, and very strong. The fibres vary in length, from a couple of inches to about 2 ft. They can easily be spun or woven, if proper precautions are used. Furthermore, asbestos is an admirable non-conductor of caloric, and it is practically indestructible by heat. All these conditions are just those which are required in a material for piston-rod packing; and it is therefore somewhat strange, that until a very recent period no one thought of utilizing asbestos for this purpose. The credit of suggesting it as a piston-rod packing is due, we believe, to Mr. St. John Vincent Day, C. E., who read a very interesting paper on "Asbestos, with special reference to its use as steam-engine packing," before the Institution of Engineers and Shipbuilders in Scotland. The new packing, we learn from this paper, was first used in America with much success, and it has since been tested in this country with results of which we shall speak in a moment. In referring to the value of the new packing, Mr. Day said: "The packing used for piston and valve rods, or spindles, has, as we all know, three prime elements of destruction to contend with, namely, an elevated temperature, friction, and moisture, and one of them only, namely, friction, has any appreciable effect on asbestos packing when the mineral is pure and properly prepared. No matter how high the temperature of the steam, how rapid the stroke of the piston, or how great the pressure of the steam, the packing seems to be unaffected by those conditions. In America, where the new packing was first used, some of it was taken from the piston-rod stuffing-box of a locomotive engine, after having been in, and the engines at constant work, for 3 months, with steam at 130 lbs. pressure per sq. in., and making an average daily run of 100 miles, including Sundays; and, as you can see by the sample shown, the fibre, with the exception of being discolored by oil and iron, is just as flexible and tenacious as originally. After having been once disintegrated, it appears impossible to so pack or mat the fibres together that they are not easily separable by the fingers."

Asbestos packing was first used in Great Britain by Mr. Benjamin Conner, locomotive superintendent of the Caledonian Railway, and Mr. Day exhibited to the members of the Institution the packing of a locomotive stuffing-box which had been used on that line from the 27th of July, 1871, to the 18th of November. The engine in which it was used has outside cylinders, and single drivers 8 ft. in diameter. The piston stroke is 2 ft. The engine was employed in working the fastest train on the Caledonian line; to wit, the 10 A. M. express from Glasgow, reaching Carlisle at 1 P. M., with three stops on the journey. The best ordinary packing lasts, under these conditions, 2 months at most, rarely so long, and the gland requires constant screwing up. The asbestos packing was apparently as good as when it was put in, and the engine had run a distance of 2,000 miles in 3 weeks, during which the gland screws had never been touched. The following letter from Mr. Conner to Mr. Day contains valuable testimony to the excellence of the packing :—

"The box herewith contains the asbestos packing put into a piston-rod stuffing-box of one of our main line service passenger engines on 27th July, and taken out on 18th November ; in that time the engine had run 14,070 miles.

"As the packing was put in coiled instead of being cut into rings, the gland was nearly home on 12th September, and an additional ring was put in at that date." In the course of the discussion Mr. Conner stated that : "The advantage of the asbestos packing over the soapstone packing was, that with the latter, at the high temperatures of steam from 125 lbs. to 130 lbs., the lower portion of the packing got thoroughly charred, and another ring had to be put in after the first week; so that in course of a month the packing had almost entirely changed. The asbestos packing being practically incombustible did not waste; he suggested that the covering of the packing should be made of incombustible material also. At first he had applied it coiled round the piston-rod continuously, but he thought it should be applied in rings. The inside of the packing seemed to him as fresh as when first put in. He believed it took less oil to lubricate the piston-rod, for the oil remained on the rod, not being absorbed by the packing. It kept the rod beautifully polished, more so than with any other packing."

We think that with such testimony as this before us, supported further by that of Mr. David Rowan, who spoke to the value of asbestos packing for marine engines, we are fully justified in holding the belief that this mineral will supply a way out of one of the most troublesome obstacles to the use of very high-pressure steam. There is, furthermore, not the slightest chance of the supply being exhausted; on the contrary, it is likely to last as long as our coal-fields. We are unable to say at present what the price of the asbestos packing is, or where it can be obtained. It is, probable, however, that when once the value of the material as a packing is recognized, its regular manufacture in this country will follow.

UTILIZATION OF COAL DUST.

From "The Philadelphia Ledger."

FRANKLIN INSTITUTE, PHILADELPHIA,
December 19th, 1871.

The Committee on Science and the Arts constituted by the Franklin Institute of the State of Pennsylvania, for the Promotion of the Mechanic Arts, to whom was referred for examination specimens of artificial fuel prepared by Mr. E. F. Loiseau, of Philadelphia, report that they have made trials of the samples produced from anthracite and from bituminous coal.

The mode of manufacture, as related by Mr. Loiseau, is as follows :

1st. Anthracite small coal and dust were mixed with (7) seven per cent. of clay, and compressed into cylindrical moulds about $4\frac{1}{2}$ in. in diameter and 4 in. deep, or else into spherical masses, about 3 in. in diameter.

2d. The moulded masses are placed for a few minutes, in a bath of benzine in which rosin has been dissolved, and from which they are removed and dried by an exposure to a current of air.

The object of coating them with a film of rosin is to prevent the absorption of moisture and consequent softening of the clay; the solution in benzine penetrates the mass of coal and clay to a depth of about $\frac{1}{4}$ of an inch and so efficiently closes the crevices that samples immersed in water for 12 hours were found dry in the interior when broken up for examination.

Both the anthracite and bituminous fuels were burned in a furnace measuring 9 in. in diameter and 7 in. in depth; each variety of fuel burned freely and was completely ashed, but the intensity of the combustion was less than that produced by anthracite or bituminous coals of small size burned in the same furnace.

These comparisons were made with a moderate and also with a strong draft.

The average amount of ash obtained from the anthracite artificial fuel was 16 per cent., and from the bituminous artificial fuel was 18.5 per cent.

The heating powers as obtained from trials in Thompson's apparatus are as follows :

One pound of anthracite artificial fuel evaporated	"	"	4.30 lbs. of water.
	"	"	8.50 "
	"	"	7.80 "
	"	"	6.76 "
An average of			6.85 "
One pound of bituminous artificial fuel evaporated	"	"	9 35 lbs. of water.
	"	"	11.11 "
	"	"	12.88 "
	"	"	10.61 "
An average of			10 90 lbs. of water.
The anthracite average is			7.40 "

The average of bituminous is 14.88 lbs. of water.

The non-uniformity of result is partly due to the imperfect manipulation in mixing the coal and the clay, and partly to the varying amounts of solution of rosin absorbed in the bath to which the material is subjected. The imperfect manipulation can be remedied by the adoption of proper machinery for that part of the process.

The ability of the artificial fuel to bear transportation is less than that of anthracite, or good lump bituminous coals, but the structure is firmer than that of any bituminous and semi-bituminous coals that are carried to market. The masses will generally break up with a fall of 3 ft., upon a stone pavement, but are strong enough to bear ordinary handling and transportation, and should they become broken would suffer no damage, unless exposed to wet.

The samples of artificial fuel examined are well adapted for use for purposes in which great intensity of combustion is not desired.

For the production of steam in stationary boilers and for household purposes it can be employed equally as well as any ordinary coal; and whenever the cost of preparation is less than the cost of mining coal, this invention will make available the immense amounts of small coal now allowed to remain useless at the coal mines. It appears to work far better than the balls or bricks of coal dust and clay and lime that came into vogue in this city many years ago, when anthracite was brought to market without preparation by the coal breaker, which had not then been invented, the balls or bricks thus made not having the protection from wet secured by Mr. Loiseau by his resinous coating.

We consider the method of preparing artificial fuel from waste anthracite and bituminous coals as presented by Mr. E. F. Loiseau, as ingenious and well adapted to the purpose, and worthy of the attention of those interested in the production of a cheap fuel, adapted to a great variety of uses.

Respectfully submitted. Signed,

Charles M. Cresson,
William H. Wahl,
John Wise,
} Sub-Committee.

REMARKS.

1*st.* The percentage of ash is larger than in ordinary coal, as the clay is not consumed; but the other advantages of the coal in point of durability, cleanliness and cheapness, more than compensate this small disadvantage.

2*d.* The samples of artificial fuel presented to the Franklin Institute to experiment upon were simply compressed by hand, and could not be made as solid as they will be when compressed by appropriate machinery.

3*d*. The cost of manufacture at the mines, including the coal and all the material, will not exceed $1 per ton.

E. F. LOISEAU.

CAR PROPULSION BY PNEUMATIC POWER.*

By JAMES A. WHITNEY, Mechanical Engineer.

Long after the success of Stephenson's engines was assured, and the superiority of locomotive traction to that of ropes actuated from stationary engines fully demonstrated, there were not wanting projectors and engineers who sought, at much cost of invention and money, to substitute the now universal mode of railway propulsion by one in which the traveling motor should be dispensed with. Nor were these without plausible argument, nor have their efforts, unfruitful in their time, been unproductive of much that may be of value now and hereafter. The original cost of a locomotive, as compared with that of a stationary motive power, is approximately as 5 to 1; it requires a fireman as well as an engineer, while an ordinary stationary engine is well cared for by a single attendant; it cannot ascend steep grades, and in wear and tear is subject to rapid and often to dangerous deterioration, even with a degree of attention which with most fixed engines and steam-generators is unusual. Add to this that the economy of fuel is much greater with the latter than the former and that fuel of poorer quality may be used, and there is good reason apparent for the numerous plans for transferring the power derived from the steam engine by some other agency than that of direct connection by pitman, crank, and axle. Foremost of the projects has been that of using atmospheric air under pressure, which has been proposed in many different forms. In open country and in direct competition with the locomotive system, it came to grief in every instance. This was not wholly a result of any engineering or mechanical objection—although such were not wanting, for a line between Paris and St. Germain was open to passenger traffic for a period of 14 years—but on the score of expense, which was found excessive.

But it must be remembered that the experiments commonly held to have settled the impracticability of the system were prosecuted under conditions the most favorable to steam locomotion as ordinarily defined. In the exigencies, however, of the present as concerns passenger traffic in large cities, circumstances are wholly changed. On account of noise, of smoke, of the frightening of horses, and of uncomfortably heating the vehicles in summer, steam cannot be used to advantage on city or street cars; neither, for several of the reasons just noted, should its use be attempted in tunnels; neither, on account of the vibrations incident to a locomotive, should such be allowed on elevated ways in which the permanent stability of the supporting structure must largely depend on the absence of disintegrating causes like that just mentioned, and on which the dangers of leaving the track, of collisions and the like, would, under the stress of crowding of city transit, be largely in excess of those experienced on common railways. It is acknowledged that horse-power is already inadequate to the needs of New York city street railways; the transmission of power by wire ropes, as illustrated in the elevated railway on Greenwich street, has proved a mediocre and insufficient method of propulsion; and in pneumatic power alone does there appear to be promise sufficient to justify the outlay required in thoroughly testing any improved system of propulsion. We use the term improved as distinct from the term new, for the plans which offer the most of utility are in their essential principles quite old, some older than the locomotive itself, and the modifications which will render them practicable will, quite likely, be in themselves very slight. But the importance of little things cannot be overestimated in adapting an engineering principle to actual use. It was the adoption of the grooved rail, permitting the flanges of the car-wheels to keep them on the track while the surfaces of the latter lay flush with the street

* Paper read before the New York Society of Practical Engineering, Jan. 3, 1872.

surface so as to offer no impediment to ordinary vehicles, that rendered street railways practicable. Had it been attempted to retain the T-rail, the city tramways, enabling 2 horses to draw 5 times as much as the team of an omnibus on a Broadway pavement, would not, as they have done, gridironed every large city in the country, made their way as an evidence of American enterprise into the capitals of Europe, and trailed their iron length along the streets of Stamboul, as it is stated they are now about to do. A careful working out of the details in the apparatus employed, the adaptation of one or the other variety of pneumatic propelling mechanism to the precise conditions most favorable to its success, and the application of more efficient means in the prosecution of the work than was possible with the inferior workshop practice of 40 years ago, will, we have faith, bring about a practical change in city and suburban locomotion ultimately valuable in every city in the civilized world having more than 50,000 inhabitants. To suggest methods by which, as the writer believes, this may be most readily and effectually brought about, is the object of the present paper.

Propulsion by pneumatic pressure may be properly divided under 3 heads, viz., that embracing the driving of a car or carrier bodily through a tube, either by an air-blast behind it, or by pressure induced in rear by a partial vacuum in front; that in which a piston operated in the same manner as in the former, but in a tube of smaller diameter, is connected to a car running on rails outside; and that in which air under compression is admitted to engines in lieu of steam, the engines being thus actuated to turn the wheels of the vehicle by approximate connections. In the first, a low pressure acting on an area if anything larger than the cross-section of the car is used: its greatest disadvantage is that, as hitherto applied, the car has been projected in darkness through a subterrene tube, reliance being had mainly upon artificial illumination. The second requires a comparatively high pressure, acting upon an area proportionally smaller than the car section, and the cause of its failure after long trial was the leaking of the longitudinal valve, whereby connection was allowed between the piston and the car arranged externally. The third is simply the use of air springs, in which power is stored by compression, to be slowly given out as the air is passed to and through the engine cylinders: among the objections attending its use is the difficulty of maintaining a uniform pressure in the supply to the engine; but of much more practical importance is the liability to freeze, induced in the engine from the heat rendered latent by the expansion of the air. These, the just enumerated principal defects incident to each modification of the pneumatic system, do not seem, in either case, to be beyond the reach of remedy, but in none does the theory or practice of such remedy appear to have been properly wrought out with special reference to the peculiar needs and conditions of city passenger transit.

The several varieties of pneumatic propulsion appear to have grown out, as it were, one from another, in a kind of natural sequence. It is 61 years since James Medhurst, in England, proposed to drive cars by an air-blast through a brick tunnel, furnished with longitudinal ledges to support the rails upon which the car-wheels were to run; it is presumed that the air current was to be produced by an apparatus similar to the blowers used in iron furnaces of that time. Fourteen years later, James Vallance patented a plan in which the air was to be exhausted in front of the car, and from the two it was but a step to combine them in such manner as to secure a maximum of speed. Apparently reflecting upon the evident objections to a tunnel railway, Medhurst, in 1827, 17 years from the date of his first project, planned what is really the germ of the second sub-system. This comprised a tube submerged throughout its length in water, and with an opening longitudinally in its under side, from each edge of which flanges projected downward, so that a water lute of several inches depth was provided to the opening. A piston, propelled by atmospheric pressure, was to traverse within the tube, and, connected by a thin metallic blade or bar with the train upon the external track above, would propel the same. The idea, impracticable in this form, was taken up by Henry Pinkus, who made the longitudinal opening in the upper part of the tube or main, and placed in appropriate relation thereto a flexible rope to serve as a valve. As the piston—moved by the pressure behind, obtained by the action of air-pumps exhausting in front of the piston—moved forward, it lifted the rope or valve to permit the passage of the colter or connection between the car or cars outside and the piston within. Although the external pressure of the air upon the valve was calculated to keep the latter in place, it was found to leak badly, and the plan amounted to nothing. In 1839, Samuel Clegg patented, in England, a valve adapted to the longitudinal slot of the tube, and remarkable for the ingenious adaptation of its structure to the end proposed. The valve was "made of a double strap of leather or raw-hide riveted between two iron plates, the top plate wider than the slot or opening, and the lower one falling into it when the valve was closed, thus completing the cylindrical form of the interior of the pipe, which had been destroyed by the aperture cut in it." One edge of the leather was allowed to rise, the other being screwed down firmly to the surface of the pipe. The lifting edge lay, when closed, against a composition of beeswax and tallow, placed on the edge adjacent and serving as a solder. The leading carriage of the train carried a trough filled with burning charcoal, and having a blade of copper projecting downward from it. This blade, being kept continually hot, and coming in contact with the valve after the passing of the colter, melted the waxy composition, and cemented the lifting edge of the valve firmly to its seat, thereby hermetically closing the tube to provide for the passage or propulsion of the succeeding train. Samuda combined with this a method of dividing the tube into sections of any desired length, and separated from each other by valves. These valves were actuated each by contact of the leading car on an external lever connecting with the pivotal bearing of the valve. This enabled a vacuum to be maintained separately in each section to propel the train its entire length, without interference with the movement of a train on any adjacent section. Means were also provided for stopping the car by air cushioned in the end of each section on the closure of the valve, independent of the movement of the train. Such was the construction of the celebrated atmospheric railway of 30 years, or thereabouts, ago, lines of which were laid, as previously intimated, in France, between Paris and St. Germain, and in Ireland between Kingston and Dalkey, and which, in one instance where the leading vehicle of a train became accidentally detached, showed its capability of propelling a single car at the rate of 70 miles an hour.

The difficulty of keeping the tube or main with its longitudinal valve, in perfect working order, having been quite manifest in the comparatively successful experiments of Clegg and Samuda, and much more so in those of Finkus, it was natural that some appliance other than the valve should be sought for in order to communicate pneumatic power from the stationary engine to the travelling car. It was doubtless this that, in 1844, led Pierre Armand Fontainemoreau to propose a pipe or main laid lengthwise of the track, and either kept filled with air under pressure or subjected to the action of an air pump to maintain therein a vacuum more or less complete. In the former case the main was to be furnished at intervals with valves opening inwards. The locomotive was provided with two cylinders properly arranged in relation to the driving axle, and furnished with devices which automatically operated the valves in the main to supply the cylinders with compressed air, in the same manner as those of an ordinary locomotive are supplied with steam from the boiler. In the event of using a vacuum in the main, the action of the engines was simply reversed, air being exhausted from in front of the pistons, so that the latter would be operated by the direct pressure of the atmosphere. So far as we know, no practical trial of this was made, but with the addition of a tank to receive a supply of compressed air in lieu of feeding the engines direct from the main, Fontainemoreau's plan might stand as the type of one of the subdivisions of the third class of pneumatic motors; for this class includes three sub-systems—that in which the air is compressed in a main extending the whole length of the line, and calculated to supply the air to the locomotive tank automatically and without stopping the train; that in which a similar main is proposed, but the cars stopped for the temporary connection of the tanks; and that in which a separate compressing power and compressed air reservoir is provided at every station. The first of these, from its theoretical completeness, is apt to please the fancy of projectors, but, from the extreme accuracy required in the fittings, will probably never prove practically successful. The second has the merit of concentrating the power in few places along the route, and of requiring but a minimum of attendance, but involves the necessity of keeping an extremely great volume of air constantly compressed. The third—although multiplying the number of engines and reservoirs—will, all things considered, probably meet with the most favor when this method of stoiing up power for car propulsion is tested as its merits, theoretically at least, deserve.

In further reference to each of the three classes of pneumatic apparatus sketched in the earlier portion of the present paper, it is necessary to consider in each the degree of utility thus far attained with it; the most feasible methods of obviating its defects; and the conditions under which it may be most advantageously adapted to the needs of travel in New York city. For whatever, in this line, can be made practically successful under the drawbacks encountered in the metropolis, need excite no apprehensions of failure in any other locality. First in importance, as in the date of its original conception, is Medhurst's earliest scheme, known of late years in England as Rammell's system, from its—in recent times—most prominent advocate, and illustrated in this country by that fragmentary undertaking, the pneumatic tunnel under Broadway, which, with a passenger car running a distance of 300 ft., has confirmed, on this side of the ocean, the favorable expectations induced from Rammell's experiments, in 1861, with baggage trucks driven a quarter of a mile through a cast-iron tube or tunnel of 2 ft. 9 in. in height, and a width of 2 ft. 4 in., narrowed at the bottom to 2 ft. 2 in. This line was worked by the partial exhaustion of the air in front of the car, and, with a pressure behind of from 4 to 6 oz. to the square inch, a speed of 25 miles an hour was obtained. Four years later, the completion of the tunnel from Holborn to Easton, $1\frac{3}{4}$ miles afforded opportunity for more complete, definite, and decisive trial. This tube in its cross section was of horse-shoe form, 4 ft. 6 in. high, and 4 ft. across. In lieu of the longitudinal shoulders which, in the experimental line, had been made to do duty for rails, common wrought rails were employed, fixed upon suitable bed timbers arranged lengthwise under them. The goods trucks weighed each $1\frac{1}{2}$ tons. A train of 4 trucks with an aggregate weight of 10 tons was forced through the tube with a blowing pressure of 5 or 6 oz. per sq. in., or a vacuum equal to about 1 oz. less, and this at a speed in no degree inferior to that obtained in the previous or purely experimental trials. The expense of transport for freight was found by careful calculation to be less than 1 penny, or 3 cts. per ton per mile, including interest on cost of engine, wear and tear, fuel, attendance, and incidental work in the establishment. About the same time another trial on a large scale was made with a brick tunnel 600 yards long, 9 ft. in height, and 8 ft. in width. The carriage was fitted with a fringe of bristles reaching nearly to the brickwork to reduce windage, and the 20-ft. fan by which the blast was furnished was driven by an old locomotive engine jacked up, and with belt-wheels substituted for its drivers. Only a small portion of this line was level; it had at one place a gradient of 1 in 15, and curves of only 8 chains radius. The car traversed the whole distance in 50 secs., with an atmospheric pressure of $2\frac{1}{2}$ oz. to the square inch. On the whole, without adverting to more extended or more recent trials, it may be assumed that, years ago, experience demonstrated the feasibility of propelling cars through tunnels by atmospheric pressure at from 20 to 40 miles an hour, while theoretically by the use combined of an air-blast and vacuum, the probability of securing a speed nearly or quite twice as great is apparent. But in the running of cars for a distance equal to that between the upper and lower parts of Manhattan Island, numerous details would require to be worked out and adjusted to secure the practical success of the system. Among these would be that of arranging for the stoppage of one car or train without interference with others in motion along the route, and which in the use of a vacuum would necessitate the adoption of a plan equivalent to the valve-separated sections of Clegg and Samuda in their otherwise quite different plan. It is true that, by the use of an air-blast, only, a continuous line of cars might be propelled by what might be termed the air cushion throughout the length of the tube, but in the event of the stoppage of the foremost on the line, danger of collision from those behind would be imminent. It is possible that modifications of the turnouts applied in pneumatic tubes for the transmission of parcels could be applied in those for passenger transit. That of Needham, an American invention, brought forward during the past few years, comprised a circuit tube, with ends connected at a suitable distance apart with the main or transit tube, and used in connection with valves which shut off, in the space between the ends of the circuit tube, a portion somewhat longer than the carrier or piston. One of the valves was shut in front until the carrier, cushioned by the air in front, was stopped. The other valve in rear was then closed, the blast being thus directed through the circuit tube around the inclosed portion of the main tube. The top of such portion, hinged for the purpose, was then opened to admit access to the carrier. With the circuit tube entering the main at a slight angle, and with automatic switch-operating mechanism to shift the rails, there seems no good reason to doubt that, by means substantially like those just detailed, cars in an 8 or 10 ft. pneumatic tube could be stopped at stations without interfering with the continued passage past of cars previously behind them in the tube.

The points to which reference has just been had wherein the development of improvements is still required are not so abstruse as to leave any doubt as to the practicability of securing them, neither can there be much doubt as to the conditions, and the sole conditions, under which the system can be applied in New York and other cities. That pneumatic tunnels of only a few feet diameter, dark in spite of gas jets, and damp in spite of the ever fresh current of air, are not adapted to popular needs and wishes, is shown by the fact that the projectors of the Broadway Tunnel are already agitating for the privilege of making a tunnel 30 ft. in width, in which this plan of pneumatic propulsion will prove inadmissible. That its use on the surface is out of the question is manifest at a glance. There remains then only an elevated railway as affording an opportunity for its use, and with such it would prove superior to any other method of propulsion yet suggested. Let an elevated pneumatic tube be carried over the buildings and cross-streets, sustained on iron supports constructed on the principle of a suspension bridge over each block; let this tube be of wrought iron for strength and lightness; lined with wood for moderate warmth and for reduction of friction to the air-blast; glazed throughout its length with panes of sufficient size and numbers to light it well; furnished with turnouts, to enable one car to be stopped at every station without interference with the others; furnished with electric signals automatically actuated by the cars themselves, to indicate their approach to the stations; and place the working of the line, from the lowest duty to the highest, in the hands of educated, careful and properly remunerated engineers, and the question of quick transit, in one of its phases at least, will be solved with greater satisfaction to the public and credit to the engineering profession than the most ardent advocates of speedy passenger travel now dare hope for. The lighting of the tube by windows, which would constitute a most essential element of success, would not, as might at first appear, be a matter of much practical difficulty. Although brittle, glass is comparatively strong, and would resist many times the pressure required to be brought upon it in working the line. An example, apropos in this connection, of the ability of glass to resist pressure, was given some years since in steam-boiler experiments of the Franklin Institute, in which the plate-glass window of a boiler withstood the pressure until it rose suddenly to 180 lbs. to the sq. in.

Allusion has already been made to the proposed supersession of the present Broadway tunnel of 8 ft. diameter by one 31 ft. in width, 18 ft. in height, and furnished with double tracks. In the plans made public, no information is given as to the motive power proposed, but it is manifest that cars running in opposite directions could not, unless the tunnel be longitudinally partitioned from end to end, be propelled by the fan-blast or exhaust used in the present experimental work. It is hardly likely that the folly of wire ropes will be repeated in this case, or that the slow power of horses will be used on a railway built at such cost. Locomotives may be attempted, but their employment, because of smoke, foul air, and jar to the foundations of buildings, should not be tolerated. The motive-power for such an underground line is not of less importance than the construction of the line itself, and the latter should, from the first, be calculated with especial reference to the former. Although the suggestion is not free from difficulties, there is good reason for the belief that the Clegg and Samuda system, a tube with a longitudinal valve-covered slot in the top, and an internal piston connected with the car running on an external track, would effectually subserve the purpose of transit through such a passage way under the streets. During the existence of the line between Kingston and Dalkey, a gross load of 50 tons was at times propelled at a speed of 50 miles an hour, the gradient being 1 in 115, the diameter of the main 15 in., the vacuum at the greatest equal to 25 in. of mercury, and the engine of 100 horse power. The leakage of the valve absorbed about 10 horse power per mile, or 30 horse power per section of 3 miles. The cost of such a railway, laid on the surface, was about $25,000 per mile, at the price of labor and material a quarter of a century or more ago. The loss of power by leakage through the valve appears to have amounted to from $\frac{1}{4}$ to $\frac{1}{3}$ of the whole. But this, while serious when in direct competition with locomotives, would be of minor consequence when the great patronage of a New York city railway warranted unusual outlay, and, as far as the ventilation at the tunnel is concerned, would prove a positive benefit to the line, though at the cost of fuel for the engine. It must be remembered, too, that the valves devised by Clegg and other projectors of his time, were, before the introduction of india-rubber, a substance better than any other adapted to such a purpose. There is apparently no good reason why a strip of caoutchouc so applied as to press laterally over the longitudinal opening in the tube, should not serve in a much more efficient degree, all the functions of the complicated device of Clegg and Samuda's railway. Should it prove too slight in tensile strength, a wire rope could be imbedded within it, and should its yielding power be found insufficient, this essential could be increased by giving a cellular consistence to the material by methods already known. The deterioration which would occur from contact of oil or grease necessarily used for lubrication, would, in the use of India rubber as just indicated, require that it have cemented upon it a covering of leather or the like.

While there can be no doubt that both an elevated and an underground railway, properly constructed, will meet with the most extended and profitable patronage from the citizens of New York, there is no reason to suppose that the surface lines will ever be given up, and on them some motive power other than horses or steam should be provided. Of the several systems of pneumatic propulsion, that which embraces tanks of compressed air, serving in lieu of steam in the driving of engine pistons, is the only one adapted to the purpose. A number of trials have been made during the past few years with alleged satisfactory results, but it is doubtful if the chief obstacles to its employment at all seasons of the year have been overcome. Among recent inventions designed to increase the utility of the system is one in which the tanks are to be made of paper, obviously to prevent as far as possible the loss of power by radiation of heat generated from the compression of air in the tanks ; another covers the use of a number of cylinders connected by tubes to form together the compressed air reservoir of the car, and which admits of a more convenient arrangement of, as well as greater strength in, such reservoir. The inventor of this also claims the combination with the heating apparatus of the car of a conducting pipe from the reservoir in such a way that the compressed air, while passing to the engine, may be heated to increase its expansive power, while still another feature of his apparatus is a muffler or box lined with soft fibrous material, to receive the exhaust from the engine and deaden its sound.

The plan of making the reservoir of non-conducting material might possess a certain advantage if the air could be used as soon as compressed, or before time for any considerable radiation has been afforded. The arrangement of the air-holding cylinders in connection with each other would afford in some cases a source of convenience, but would not be essential to the arrangement of the cylinders with regard to economy of space, as the cylinders might, in succession, be brought in communication with the engines. The need of the muffler seems doubtful, and, as the air could hardly leave the cylinders quite reduced to atmospheric pressure, it would probably be much better to throw the exhaust into the car-heating furnace in winter to urge the blast, and in summer into the body of the car to cool the atmosphere therein. The heating of the compressed air to increase its power of expansion would be likely to be of advantage only when incidentally incurred in protecting the cylinders from the congelation of vapor contained in the air, and liable to be frozen by the absorption of heat by the expansion of the air in working the engine. To this end, it would be advisable to arrange the cylinders within annular jackets in open communication with the furnace used for warming the car, and which should be constructed with especial reference to this use in connection with the driving motor. This last should furthermore be so applied in connection with the brakes, that the throw of a lever would instantly turn the pneumatic power from the propulsion of the car to its stoppage, which, by this means, could probably be accomplished in less time and within a shorter space than could be done with horses at an equal speed. There is in addition to those just specified another point which is now beginning to attract the attention it deserves, viz., the regulation of the inflow of air to the cylinders. This has been accomplished, it is claimed, by very simple devices, and, indeed, the mechanism need not be complex, for the connection of the stem of a pressure-gauge with a valve governing the size of the cylinder inlet-ports would seem to fully embrace the principle of an efficient device for the purpose.

The elements enumerated as essential to the success of the system will necessitate the construction of a street car radically different from those now in use, especially in the matter of weight. But there should be no difficulty in reducing the weight of the car, so as not to exceed, with its engines and reservoir, 9,000 lbs., the weight of the clumsy vehicles that now traverse the tramways of New York.

In conclusion, such in brief are the ideas of the writer on the most important application yet suggested of so-called pneumatic power. As to how far they will ever reach fruition in the solution of the vexed question of city transit, it is impossible to say. But they have been deduced, without reference to any especial plan or theory, from the actual results of recorded practice, not less than from the well-known laws of science, and have led him to believe that passengers may be cheaply carried to and from the City Hall at from 20 to 40 miles an hour with all the comfort of ordinary railways, and none of the dangers or inconveniences incident to the employment of locomotives.

SWISS METHOD OF DRIVING PILES.

From Professional Papers of the Corps of Royal Engineers.

During a tour in Switzerland, the following method of driving piles was seen being successfully employed at the town of Visp, after an inundation of the river of the same name.

The inhabitants required a bridge over a rapid and shallow river of about 5 or 6 ft. in depth, and 80 to 100 yards in width. Moreover, as traffic was suspended until the bridge was completed, celerity was of the utmost importance.

The bottom of the river was composed of stones and fine sandy silt, such as is generally washed down from the Swiss mountains during heavy rains. A bridge on small piles was adopted as a temporary plan to restore the diligence route during the repair of the old retaining wall of the river. The method of driving the piles, which was new to me, seemed so efficient that I reported upon it to Major-General Sir John Simmons, C.B., R.E., on my return to England.

The piles used were about 12 ft. long, and 5 in. in diameter; the bottom of the pile was merely pointed, and was not shod with iron, neither was the top protected with a ring or other contrivance to prevent the pile splitting. A $\frac{3}{4}$ in. hole, about 9 in. long, was bored in the top of the pile, and a $\frac{3}{4}$ in. iron bar, 6 or 7 ft. long, was driven into this hole, and acted as a guide bar on which the monkey slid. The monkey consisted of a piece of round oak, about 10 in. in diameter, and 30 in. long.

It had a strong bond ring at each end, and through its central axis was an inch hole from end to end, in which a guide bar could easily slide.

There were four bent handles of bent ash, projecting from the body in the arc of a circle, and fixed to it under the bond rings. There were also some smaller monkeys with only three handles.

The men who worked the monkey stood round it, and worked it vertically, taking time from the leading hand, who gave a lusty shout when they were to heave; after lifting it as high as they could, they assisted the fall by a strong vertical downward pull. Sir John Simmons allowed me to make some experiments in the fieldworks at Chatham, and to form a pile bridge, by driving the piles in the manner above described. The monkey used consisted of a piece of round oak $9\frac{1}{2}$ in. in diameter, and 3 ft. 6 in. long, and it had a central hole $2\frac{1}{2}$ in. in diameter, bored from end to end, and then burnt out to get a smooth surface.

It had four handles, made of $\frac{3}{4}$ in. round iron; they were flattened out at the ends, and a hole made through the flattened part, by which a wood screw fastened the handle to the monkey, the wood being slightly cut away at that part, and the outer part of the handle thus brought flush with the surface; a shoulder, however, was left on the handle to butt against the bond rings. The bond rings were made of $\frac{5}{16}$ in. iron, and were 2 in. broad. They were shrunk on after the handles were attached. Much difficulty was found in making the wooden handles stand the shock of the concussion; but after iron handles, as described, were used, no further trouble was met with. As the $\frac{3}{4}$ in. handles were rather small for the hand, they were served with spun yarn.

I was anxious to devise some method by which the platform, upon which the men who worked the monkey stood, should be fixed to and supported by the pile itself, so that their dead weight should push the pile deeper after the blow had moved it and disturbed the mud and earth surrounding it.

I tried several plans, and when $\frac{1}{4}$ in. iron plate can be procured, and a forge and a good smith are at hand, the best seemed to be as follows:—

The platform itself was of wood, formed of planks and battens; it should be circular in shape, and should have a central hole large enough to take the largest pile that is to be driven.

This was supported on two clips of iron which were cut out of $\frac{1}{4}$ in. plate, bent to a right angle, and again bent at the centre to receive the pile; two of these were then riveted together by similar arms to form one clip, the other two arms being drilled with suitable holes for screw bolts which attached the two clips firmly together, and caused them to grip the pile.

When the platform was about 15 in. below the top of the pile, the men could work with the greatest force.

Should there be no forge at hand, the following method can be resorted to if the piles have not to be driven to a greater depth than 4 or 5 ft.

Two planks 20 ft. long, 3 in. thick and 12 in. broad, had each a hole bored through the centre at a distance of 1 ft. 7 in. from the ends and a diamond-shaped jaw 9 in. long and 5 in. broad, was made at a distance of 2 ft. 2 in. from one end; the ends of the planks were connected together by 4 turns of No. 8 iron wire, which passed through the holes at the ends near the jaws; the other ends were connected by a lashing after the planks had been lifted over, and their jaws had embraced the top of the pile to be driven. In order to prevent the planks slipping down the pile, a lashing was tied around the latter about 15 in. from the top, and some strong iron spikes driven in below the lashing; and to prevent the planks toppling sideways, an iron hanger was made. This could be replaced with wire or small strong rope from the pile top to the outside of the planks, where it could be fastened to a projecting batten, or to spikes suitably placed.

The plan that seems the best for bringing the piles into position is as follows: The length of bay should not exceed 10 ft., and it is easier to work with a bay of 8 ft. Two strong poles about 20 ft. long and 5 in. in diameter, are bolted together at one end about 7 in. apart; they are then lashed down to the last bay; 2 planks are laid on them and the pile taken out point foremost and dropped into its place. A small cross piece is then lashed on the ends of the spars to prevent the pile falling outwards. The iron clamp and circular platform, or the plank platform, is then put on, and the guide rod and monkey brought out and placed on the pile by two men; the remainder then follow, and the pile is driven until the bottom of the platform is brought down to the poles. The driving party then come in, bringing with them the monkey and guide rod; the platform is next brought in, and the transom and rod-bearers are duly lashed in their places.

Experiments.—A Norton's tube-well was driven 14 ft. in less than half an hour.

Short piles, 6 in. diameter, were driven in hard ground at the rate of 18 in. per min., a platform clamped to the piles being used to carry the driving party of four men.

A pile bridge 90 ft. long and 10 ft. wide with bays 12 ft. or 13 ft. long, was made by 10 sappers in 41 hours of actual work. The average weight of each pile was from 90 to 100 lbs., average diameter 6 in. top and 4 in. bottom, average length 20 ft. The nature of the bottom in which the piles were driven, was 12 in. of mud, and a thick layer of gravel. The weight of the monkey being a little more than 1 cwt., it will be seen that the piles were rather heavy; nevertheless they were driven at an average rate of 1 ft. in 4 or 5 min., and sometimes as fast as 6 in. per min.

Sir John Simmons proposed that a lengthening tube of Norton's tube-well should be used as the guide bar; it was tried, and answered the purpose admirably. It was found to be important that the hole bored in the top of the piles to take the guide bar should be quite vertical when the pile was being driven, otherwise the friction between the monkey and the bar was apt to pull the latter out of the hole.

It was found that there was no necessity to bind the tops of the piles to prevent them from splitting.

The men preferred working on the platform with iron clips, as they had more room and a more stable footing; with the plank platform, also, some difficulty was experienced in lifting the heavy planks over the head of the pile. The time necessary to get them into position was nearly the same.

STEAM ENGINE CYLINDERS.

From "The Engineer."

The correspondence which has recently appeared in our pages on the subject of jacketed cylinders affords ample proof that much has yet to be learned about steam engines even by otherwise able and competent engineers. Any one favored with opportunities for acquiring information concerning what is being done by the most successful firms, will soon discover if he think proper, that even when excellent results are obtained as regards economy of fuel, they are but too often got by the application of the rule-of-thumb system to in one sense very recondite problems. It was discovered as far back as Watt's time, that by keeping a cylinder hot, less fuel was required to do a given amount of work than sufficed when the cylinder was cooled down by sending injection water directly into it. The separate condenser got rid of the injection water; but it was soon perceived that this was not enough, and the steam jacket was added with advantage. Almost every engineer knows nowadays that a cylinder should be kept as hot as possible; but very few makers of steam engines understand the precise reasons why a cylinder should be kept hot. If questioned on the point, they say glibly enough: "If you don't keep it hot the steam is condensed and wasted;" but in almost all cases the belief is held that the dreaded condensation takes place by conduction through the substance of the cylinder to the outside. Of course there are men who know better, but we are not speaking now of particular firms, but of the great mass of engine makers, who, if they used jackets at all, use them with but a dim glimmering of an idea concerning the principles on which they operate for good. We have explained and re-explained the action of the steam jacket and the phenomena which occur within a cylinder, we hope with benefit to some individuals; but it is none the less certain that we may now treat the subject from a slightly different point of view without saying something that every one is sure to know all about beforehand.

Let us see how much steam it is possible to lose by leaving a cylinder and its appurtenances absolutely unclothed. We may for practical purposes regard the cylinder under such circumstances as an air surface condenser. Peclet, our great authority on these questions, shows that if a current of air at 59 deg. Fahr. be suffered to flow over cast-iron tubes, steam will be condensed within them at the rate of 0.36 lbs. per sq. ft. per hour. The cylinder of a steam engine is a tube, and air circulates round it because, being warmed by the heated metal, it continually rises and is replaced. Now a fairly good engine will give one horse power indicated for every 30 lbs. of steam passing through it per hour. On Peclet's data, the quantity of surface required to condense 30 lbs. of steam per hour would be 10.8 sq. ft. To be on the safe side, however, and to eliminate fractions, we shall suppose that every 10 ft. of unclothed surface represent a loss of 1-horse-power indicated per hour. Let us see how this fact will apply in practice. The cylinder of an 8-horse portable engine is, we will say, 9 in. diameter. The piston stroke is 14 in. Then the surface exposed by the cylinder, valve chest, lids, etc., will not be far short of 6 sq. ft. The loss incurred therefore by not clothing the cylinder as far as external cooling is concerned, will amount to about .6 of a horse-power per hour, and this loss will be approximately constant whatever the weight of steam passed through the engine. As, however, .6 of a horse-power bears an appreciable proportion to the power likely to be developed in such a cylinder, it is worth while to lag the cylinder carefully, by which the loss will be reduced to a mere nothing. Let us turn now to an engine of, say, 250-horse power nominal. We shall allow as before 10 circular inches of piston per nominal horse. In other words, the cylinder will have a diameter of 56.5 in. nearly. Let the stroke be 8 ft., a common proportion. The cooling surface of such a cylinder with its appurtenances would be about 170 sq. ft., which would suffice to condense about 17 horse power of steam per hour. If the engine indicated 500-horse power the loss would therefore be very nearly $\frac{1}{30}$th of the whole work done. If the portable engine worked up to 16-horse power, the loss would be nearly $\frac{1}{26}$th. It is more probable, however, that the large engine is worked to three times, than it is that the portable would be worked to twice its nominal power. It is evident, in any case, that small cylinders require to be more carefully clothed than large cylinders. Clothed or unclothed, however, no conceivable theory based on the passage of heat to the outside of the cylinder will account for the enormous condensation which takes place in unjacketed engines expanding steam more than two or three times.

We have before now shown that if it were possible to construct a cylinder of perfectly non-conducting materials, we should have the nearest possible approach to a perfect steam engine. The temperature of the cylinder would have no effect whatever on the steam, if the metal were absolutely incapable of absorbing heat. The action in such a cylinder would be as follows:—Saturated steam would enter from the boiler at the beginning of each stroke. As work was performed a portion of the steam would be condensed, and as expansion proceeded the temperature of the steam would fall, but no condensation would take place, as a consequence of expansion alone ; on the contrary, as the total heat of steam slightly augments with each rise in pressure, steam, when suffered to expand without doing work, becomes sensibly superheated. As, however, in the case under consideration, condensation would take place, because the loss due to the performance of work greatly exceeds the trifling gain proper to expansion, it follows that a small quantity of water would probably be deposited on the sides of the cylinder, piston, etc., but not much, because the condensation proper to the performance of work taking place through the whole body of the steam, the water would be held in suspension and carried off to the condenser. The indicator curve would be lower than that proper to Marriotte's law by an amount measured by the condensation and consequent reduction in the volume of steam, caused by the performance of work. At the end of the stroke the steam would rush to the condenser, but no re-evaporation of water deposited on the sides of the cylinder would take place other than that proper to the sensible heat of the deposited moisture. When the return stroke was complete, and steam was admitted for the second time, it would find the cylinder in precisely the same condition as at first; there would be no condensation due to cold surfaces, and so the process would proceed, and the maximum economical result would be obtained. Now, in practice, it is impossible to obtain a cylinder which is an absolute non-absorbent of heat, but we can bring the metal of which it is composed to such a condition, that it may be regarded as perfectly neutral. It is well known that when two bodies have exactly the same temperature, no interchange of heat will take place between them. If, therefore, we heat the cylinder to precisely the same temperature as the entering steam, no condensation will take place. The metal may be regarded as neutral, and the action will be just the same as that in a perfectly non-conducting and non-absorbing cylinder. We can reduce the cylinder to this condition by the application of a jacket. If the engine worked without expansion, no transference of heat from the jacket to the cylinder would take place, except that due, first, to the fact that the steam within the cylinder would fall a little in temperature owing to the performance of work—and even this effect would probably only take place because it is impossible to work an engine without cutting off communication with the boiler before the stroke is complete; and, secondly, because the cylinder, being opened to the condenser at the end of the stroke, its inner surface would be made cooler than its outer surface; consequently heat would be transmitted to the condenser from the jacket. If, however, the interior of the cylinder were quite dry—as it ought to be—the loss from this cause would be very small. It is certain, however, that a considerable quantity of steam is condensed in all jackets beyond that which can be accounted for by the work done; and this is no doubt due to the fact that the metal of the cylinder is kept, necessarily, at a temperature intermediate between that of the jacket and that of the condenser, though nearer to the former than the latter. Just at the end of the stroke the inner surface of metal is so far cooled down that even when the jacket is used a small quantity of steam just entering is condensed. This is not re-evaporated until near the end of the stroke, and then it is done at the expense of the steam in the jacket, and it acts especially injuriously in that it wets the steam flowing to the condenser, and thereby renders it a good conductor. It must not be forgotten that heat takes some little time to traverse the sides of the cylinder. It is quite possible, therefore, that a sudden rush of wet steam at the opening of the exhaust may reduce the temperature of the inside face of the cylinder very considerably, and before heat can reach this surface again from the jacket, the steam port opens, and the fresh steam comes at once in contact with a surface some degrees colder than itself. Water is deposited, and has to be re-evaporated at the expense of the jacket, and so represents a dead loss, in that it has been twice evaporated and done work but once. From this it appears, first, that the sides of the cylinder should be made as thin as possible; and, secondly, that they should be of good conducting material. It may be urged that, under these conditions, the condensation in the jacket will be increased because of the influence of the condenser during the exhaust; but this argument has no force. If we but keep the exhausting steam and the sides of the cylinder, etc., dry, there will be no sensible loss. Experience has proved that practically no condensation occurs in a jacket when the engine is kept standing for long periods at the end of its stroke, communication being freely open between the cylinder and a condenser holding a good vacuum. Paradoxical as it may seem, the best way to prevent useless condensation is, as we have said, to make the material of the cylinder as thin as practicable and of the best possible conductor.

There is a practical objection to the use of the jacket to which we have not yet referred. High-pressure steam, especially if quite dry, appears to exert a peculiar solvent effect on cast iron. Already we hear rumors in numerous directions of the rapid wear of the high-pressure cylinders of compound engines, an evil which grows in proportion with each augmentation of the weight of the casting. It appears to be fortunate that the remedy for this evil affords the best possible method of applying the true theory of the jacket in practice. In certain cases the jacket is made by putting a thin steel tube into a cast iron cylinder bored out to receive it. The Reading Works Company have brought this system of construction to great perfection, for example, with excellent results. How far the scheme is applicable to marine engines we are unable to say. We suggest that, especially in marine engines, instead of steel—notably an uncertain material—hard brass, or, more strictly speaking, gun-metal liners should be used for the high-pressure cylinders. Properly made the material is much harder than cast iron, and will take a beautiful surface ; while the material being an excellent conductor, would comply with one of the fundamental conditions of eminent success in using the jacket. The idea is a mere extension of the system of lining air pumps. We do not claim it as original, but we believe this is the first time the scheme has been mentioned in any journal; and it appears to us to be well worth the consideration of engineers engaged in the construction of large steam engines working with considerable pressure.

THE LIVING FORCE OF COMPRESSED AIR.

By Mr. PERRIGAULT.

Translated from "Les Mondes."

The velocity of a jet of condensed air escaping from the base of a fan is determined by means of the formula

$$v = \sqrt{2\,g\,h};$$

v being the velocity, and h the height obtained by dividing the effective pressure P by the density d' of condensed air, deduced from the pressure in the reservoir.

But if the formula $d'\,h$ or $\frac{1}{2}\,m\,v^2$ is employed in determining the living force of a cubic metre, we get only the measure of the living force produced by a non-elastic fluid of density d', without finding the value due to the elasticity of compressed air.

To determine the total mechanical effect, we must employ another height, H, equal to $\frac{P}{d}$, d being the density of air before compression, under the hypothesis that the work is effected without any loss of the heat generated by the condensation.

Suppose, for example, we take 1 cubic metre of air at the temperature of 112°, 25 – 112, 25 $d = 1^k.293 \times 1 - 0{,}003665 + = 1^k{,}822$.

We condense the cubic metre to 2,994 at m absolute. In this condition it would equilibrate a column of water 20600 m/m high.

$$H = \frac{20600}{d} = 11306 \text{ metres}$$

The number of heat-units produced, admitting that the mechanical equivalent of a unit is 425 kilogrammetres is

$$\frac{11306}{425} = 48^c\,47.$$

The increase of temperature, supposing that 0°,237 raises 1 kilogramme of air 1 deg., is

$$\frac{48^c.47}{0{,}237 \times 1{,}822} = 112°.25.$$

The volume under pressure becomes

$$\frac{1 \times 1 + 0{,}003665 \times 112°.25}{2{,}994} = 0{,}471 \text{ litres.}$$

The cubic metre of this air, so condensed, would be composed of 2 cubic metres 123 litres of non-condensed air at the temperature—112°,25 ; and the density would be

$$2{,}822 \times 2{,}123 = 3^k{,}87.$$

Finally, the total work stored up in one cubic metre before compression would be $T\,r = H\,d$; after compression, $T\,r = H\,d'$.

I have made use of this high pressure of 1,994 at m., a pressure not realized in fans, in order to compare the results of the above calculation with those obtained by M. Tresca in the remarkable experiments made by him.

On the 12th February, 1865, he condensed air in a condenser of the capacity of 3 *mc.* 208 litres. The effective pressure was 1,994 at m., or 20,600 *mm.* of water, and the temperature after compression was zero. He allowed the condensed air to escape by opening a valve 10 times, keeping it open a very short time, generally about 5 sec. At each discharge he restored the temperature.

Before the first discharge the monometer indicated a pressure of 2,275.51 of mercury; and after the last discharge, 0,823.90 *m.*

The useful expansion was, therefore, 1,451.61 *m.* of mercury, or 19,730 *mm.* of water, the total pressure reading 20,600.

The temperature rose to 102°,18. But it was remarked that during the time of each discharge the reservoir imparted to the air contained in it an appreciable quantity of heat, and that this emission would diminish 5 per cent. the lowering of temperature, which, under these circumstances would have reached 107°,289.

The density of the compressed air was 3.87 *k.* The cooling being proportional to the pressure, we can determine the fall if the expansion were equal to the atmospheric tension, by means of the proportion 19,730 *mm.* of water : 107°,289 : : 20,600 : x=112°,02. Let us now compare the results of our calculation with those of M. Tresca. Proceeding in an inverse manner, we take air compressed at 1,994 at *m.* and allow it to expand. The original temperature was 107°,289 for an expansion of 10,730 *mm.* of water. Hence, if the expansion had been 20,600, the temperature would have been 112°,02.

Is it possible to justify a method of calculation by a more confirming experience?

The first consequence is that the mechanical equivalent of heat appears to be precisely 425 $k. \times m.$

The second, is that a cubic metre of air at any density, when compressed to a tension P measured in *mm.* of water, will develop $\frac{P}{425}$ heat units, and that its temperature will rise from $\frac{n\,c}{d}$ degrees n heat units. The work stored up will be $\frac{P}{d}$. The living force of a cubic foot of air compressed by a column of water will be equal in kilogrammes to the number of millimetres of the column which is the measure of compression for a cubic metre, measured before compression.

H d expresses the total work of the jet of a cubic metre condensed, measured before compression.

H d', after the compression.

h d, and h d', are the work without expansion.

The expansion of a jet of air, or the dynamic expansion, is H $d' - h\,d'$ measured at the bottom of the fan. This differs essentially from the expansion in the air.

CHARLES BABBAGE, PHILOSOPHER.

From "The American Exchange and Review."

"LONDON, Oct. 21, 1871.—Charles Babbage, mathematician and philosophical mechanist, and author of several mathematical works, died yesterday, aged 79 years."

When we read in our morning paper the above despatch by the Atlantic cable, a host of impressive memories rose to our mind, and have been haunting us ever since. For, from boyhood to the present day, the wonderful works of this man have had for us a fascination and a delight. We have come to think of him as of a much prized old friend, and we feel almost a sense of personal loss at his death, a feeling intensified by the knowledge that it is rare to find thought so clear and profound as his, united with such skill in embodying its results in useful art.

He was not well known to the present generation; but 30 years ago, Babbage's calculating machine was an object of interest to the ingenious and of curiosity to the unlngenious of both continents. That this interest and this curiosity have now almost died out, that frequent newspaper items no longer stimulate them, that the incomplete machine itself rests in unnoticed obscurity—these things, we believe, indicate not that his inventions were useless, only that they have not been properly used. This we shall make some attempt to explain.

The calculating machine was intended to construct mathematical tables. To most readers this may seem of comparatively little moment in a practical point of view.

Those who are unaccustomed to use tables cannot form any adequate idea of their value. They know that there are such things as tables of logarithms, and of sines, tangents, and secants; they may have learned how to use them at school, but they do not regard them as having any relation to their every-day lives; they do not know how intimately they are interwoven with our houses and furniture, our clothing and food. Yet in so far as any of these things depend on commerce, there is the most direct connection. The navigator determines his longitude by observations of the moon's distances from the sun, the principal planets, and certain conspicuous fixed stars. Long and laboriously calculated tables tell him the positions of these stars at Greenwich; and then, by certain calculations involving several other tables, he infers his own position and can tell how to direct his course. No less than ten numerical tables peculiar to each star are required to predict its exact position; and as the mariner is furnished with tables for 100 such stars, 1,000 such tables are constructed. These 100 stars, however, are not as many as could be desired, considering the wide range of the moon through the heavens, particularly as an accurate method of determining the longitude consists in observing the occultation of a star by the dark edge of the moon. There are at least 1,000 stars so situated as to be at some time in the moon's path, and to exhibit these desirable occultations. To predict these all would require 10,000 tables. The stars from which lunar distances may be taken are still more numerous. It may safely be said that the nautical almanac does not now furnish more than a small fraction of that aid to navigation which it might be made to supply with greater facility and accuracy in the construction of tables. We have mentioned here only one class of its tables. There are others of almost equal extent and importance. And when we leave navigation and come to surveying, mining, engineering, and in fact almost every department of commerce and the useful arts, the number of tables required swells to formidable proportions. Still more is this the case in more purely theoretical science. In astronomy their name is legion; as natural philosophy approaches perfection, they enter into its records in a continually increasing ratio; and they are beginning to swarm in chemistry and meteorology. Considering, then, the infinite number of delicate connections which we can trace between the theoretical and the practical in our progressive civilization, and the infinite further number whose existence we have reason to infer, though we cannot perceive it, we may form an estimate of the high importance of having these tables readily and accurately calculated.

We say accurately as well as readily, for the human mind is unreliable as well as tedious. Nothing but the unerring motion of well made machinery can be trusted. Civilized governments have expended millions of dollars in employing the highest mathematical talent for the construction of the most important tables, yet hundreds of errors have crept into the best of them. Mr. Baily detected more than 500 in the solar and lunar table from which the English nautical almanac had been for a long time computed. Another mathematician detected 1,000 in some tables published by the Board of Longitude for finding the latitude and longitude at sea. In a mere multiplication table extending to 100 times 1,000, computed by Dr. Hutton for the same board, a single page was found to contain 40 errors. And some tables which they published for the correction of the observed distances of the moon from certain fixed stars are followed by a table of acknowledged errata, extending over 7 folio pages. But even this latter table is not correct; a considerable number of errors have been detected in it, so that errata upon errata have become necessary. Even if tables are independently calculated by several persons, it is found that certain kinds of errors are likely to be made by all.

Now, although the mathematical formulæ on which tables are based, are many of them of the most abstruse and complicated nature, it happens that a comparatively simple process, called the method of differences, can nearly always be used in their computation. We shall endeavor to illustrate this method in one of its simplest cases.

Let us take the increasing series representing the number of cannon balls in a triangular pyramid. The numbers are 1, 4, 10, 20, 35, 56, etc., as may be ascertained by experiment, piling up marbles or other round bodies. If we subtract each of these numbers from the one next after it, we obtain the following series of differences: 3, 6, 10, 15, 21, etc. Repeating the same operation with this series, we obtain a series of second differences, 3, 4, 5, 6, etc. In the same way we find a series of third differences, 1, 1, 1, etc.

Table	1st difference.	2d difference.	3d difference.
1			
	3		
4		3	
	6		1
10		4	
	10		1
20		5	
	15		1
35		6	
	21		
56			

Now it can be proved that in this series, no matter how far extended, the third difference will always be the same number, 1. This being the case, the table may be continued to any extent in the following manner: Take the next third difference, 1, and add it to the last second difference, 6, producing 7; add this to the 21, producing 28; then add this to the 56, producing the next number in the table 84. The operation may be tabulated thus:

Table.	1st difference.	2d difference.	3d difference.
1			
	3		
4		3	
	6		1
10		4	
	10		1
20		5	
	15		1
35		6	
	21		1
56		7	
	28		
84			

So, having started the table, the rest of the work becomes simple addition—addition, too, always beginning with the same number. In most mathematical tables this number is a very small decimal fraction, and does not occur till the fourth, fifth, or sixth order of differences. If, then, machinery for adding be properly contrived, and some means provided of constantly introducing this invariable number, this final difference, whatever it may be, we have Mr. Babbage's difference engine. The constant number may be introduced by the mere notion of a spring, a descending weight, or any other regularly acting force. After being set the machine requires no mental attention whatever, except to record its results as they are successively shown on the dials. If Mr. Babbage had completed it, even this would have been unnecessary; for he had invented and drawn the plans for an attachment by which the results should be printed as fast as they were attained. By particular grooves in the types, corresponding to the numbers shown on the machine, he had even provided that at any given time the engine would not pick up any type but the right one, and would consequently be free from any liability to error caused by incorrect distribution of the types.

The fundamental nature of machinery for adding may be thus explained: Suppose a wheel with the digits 1, 2, 3, 4, 5, 6, 7, 8, 9, and 0, at equal distances around its circumference. Suppose 6 at the top; to add 7, let the finger, or a weight, or any force, turn it seven of the equal parts more. There will successively come to the top, 7, 8, 9, 0, 1, 2, 3. But 13, not 3, is the sum of 6 and 7. How is the 1 ten to be marked? That requires a tens' wheel marked with the same digits as the units' wheel. The units' wheel has a projecting tooth, and the tens' wheel has indentations into which this tooth fits so as to turn the tens' wheel 1-10th of a revolution, Then the tens' wheel marks 1, as the 0 of the units' wheel succeeds its 9, making up 10. The unit wheel goes on, as we have said to 3, making the complete reading 13. Add 8 more. The units wheel marks 4, 5, 6, 7, 8, 9, 0, 1. At the 0 the tens' wheel has been moved again, and now marks 2. We read in all 21. It is obvious that the extension of the same principle to hundreds, thousands, etc., requires only additional labor and repetition of parts. Mr. Babbage's machine would extend its work to 100 places of figures; and when set for multiplication, which, it must be remembered, is only a compendious form of addition, would multiply together two numbers each containing 50 figures.

Of course, we have here explained the mere elements of machinery for adding. We have described nothing beyond the process of adding the last column of differences. (In Mr. Babbage's engine it might be the sixth, if required.) The main difficulty consists in the transference of the results from one column to the next preceding, *i. e.*, from one set of wheels to a similar set next to it. The units' wheel of the latter set must be moved not only through as many unit spaces as the one preceding it—this would be easy—but each time through as many as are indicated by the continually increasing *results* arrived at in the former. Thus, suppose that at a certain stage of the process, when the first units' wheel adds 1, that of the next series adds 6; then the next time the former adds 1, the latter must add 7, and so on. This requires a very difficult combination of mechanical powers, continually increasing in intricacy as we go back from difference to difference until we come to the desired tabular number itself.

The difference engine was commenced for the British Government by Mr. Babbage in 1823. He had for some years devoted much thought to the subject, and had constructed for himself a small engine on the same plan, extending to two orders of differences. The expectations of the inventor were that the machine would cost £3,000 or £4,000 sterling. He was, however, a wonderful mechanist, probably the best in England, and kept continually devising new adjustments to avoid all possibility of derangement in the machinery from friction or otherwise, requiring everything, too, to be finished with an accuracy previously unattained in mechanism ; so that the expense grew greater and greater beyond the anticipations of the Government, though only reaching a small fraction of the amount which it would save to the Government when completed, to say nothing of the gain in accuracy by all who use tables. It became very annoying to Mr. Babbage to go to the first Lord of the Treasury for grants of money which were made unwillingly and after much questioning.

The Government more than once asked the Royal Society to give an opinion about the matter; and after an investigation of the inventor's plans and an examination of the finished part of the engine by many of the most eminent men of science in England, the reply was invariably that there was no doubt that the engine could be constructed, and that it would be well worth the expense when completed.

In 1833 a difficulty with the engineer, owing to the dilatory manner in which the payments were made, caused the suspension of the work; and before the Government could or would make better arrangements, Mr. Babbage had so far progressed in his speculations on the subject as to have applied to calculating machinery the principle of the Jacquard loom, and planned a machine capable of performing any calculation or developing any formula that the human mind could conceive. He thought it his duty to communicate this fact to the Government, conceiving that it might induce them to discontinue the first and undertake the construction of the second engine, which, though much more efficient, was likely to be much less expensive than the former. The Government, or rather the successive Governments of England from 1833 to 1842, now and then discussed the matter, and at the latter date finally concluded not to go on with the work. Mr. Babbage had been continually for 9 years pressing for a decision on this point; and when it was arrived at, he at once dismissed the incomplete difference engine from his mind, and devoted his energies and his fortune to the perfection of his proposed analytical engine.

The difference engine had cost the Government about £17,000 and Mr. Babbage the best 10 years of his life. He received no compensation for his services, and asked none. For upwards of 20 years he employed in his own house and at his own expense, workmen of various kinds, to assist him in making experiments necessary for attaining a knowledge of every art that could possibly tend to the perfection of his inventions ; and with the same object he frequently visited the manufactories of Great Britain and the Continent. He estimated the expense to himself at upwards of £20,000.

In the course of his labors on the new analytical engine, he built a forge and a foundery, extensive workshops, and a fire-proof building for his drawings and draughtsmen. The great difficulty consisted in the reduction of the *time* required for adding. Evidently, if all calculations were made on the bare principle, which we have explained, of turning a wheel 1-10th of a revolution for each unit added, the construction of a single important table would become the work of many years. We have only hinted at the complex nature of the machinery necessary to overcome this difficulty. Mr. Babbage now labored incessantly on it, each succeeding improvement advancing him a step or two. The intricate relations that soon arose among the various parts of the machinery became altogether beyond the power of the memory. He overcame that difficulty by devising a language of signs, a mechanical notation by means of which he succeeded in mastering trains of investigation "vaster," he says, "than the years ever allotted to one individual could otherwise have enabled him to control." These signs indicate briefly the shape of every part of a machine, the position of every part, the connection of every part with the others, the kind of each movement, the *extent* of each movement, the duration of each movement, and the actual space occupied by the various parts compared with the waste space about the machine. Thus it can be ascertained at a glance which motions are contemporaneous, and which successive, so that the same space may be occupied at different times by different parts of the mechanism. It can also be proved whether a given machine can or cannot exist, and if it can, whether it will or will not accomplish its desired object.

The analytical engine soon began to make serious inroads upon Mr. Babbage's fortune. He resolved, however, to pursue it to the extent of his ability. When he had fully explained the circumstances to his venerable mother, she replied: "My dear son, you have advanced far in the accomplishment of a great object, which is worthy of your ambition; you are capable of completing it; my advice is, pursue it, even if it should oblige you to live on bread and cheese." Thus encouraged, he went to work with redoubled energy. The undertaking was more stupendous than he supposed; or, rather, his inventive genius led him to continually add improvements which involved time and labor. In 1864 he wrote: "If I survive some few years longer, the analytical engine will exist, and its works will afterwards be spread over the world." We do not suppose that he left it completed at his death. We only hope that he left it sufficiently advanced to enable and induce others to complete it. The plan in its details was sufficiently perfected in 1852 to show to the Royal Society, whose committee reported that there could be no doubt of its feasibility and effectiveness.

Mr. Babbage published several works of great importance, the best known of which is the "Economy of Manufactures and Machinery." A more thoughtful book, and one better calculated to arouse thought, can scarcely be found; and though first published over 40 years ago, it has lost none of its value at the present day. He also wrote a lucid yet profound book which he called "The Ninth Bridgewater Treatise," being a discussion of the bearings of mathematics on religion. One of its most striking features was a mathematical demonstration that no matter what amount of experience rendered a miracle unlikely, the independent testimony of a comparatively small number of reliable witnesses was enough to establish its credibility. We think that he did not make sufficient allowance for the liability of an honest witness to be deceived, or to misinterpret what he saw; but he must be said to have conclusively answered all who hold that a miracle is an impossibility. "A miracle," says he, "has nothing in its nature inconsistent with our belief of the uniformity of nature. All that we see in a miracle is an effect which is new to our observation, and whose cause is concealed. Its credibility depends on the nature of the evidence by which it is supported." He curiously illustrated the truth that events of the most unexpected and unusual kind might yet happen according to a known and foreseen law, by an experiment with his difference engine. Taking some friends once to see the engine, he set it to count the series of natural numbers, 1, 2, 3, 4, 5, 6, etc. After continuing the series for a while, he pointed out the fact that it was impossible for the machine thus set, from its very structure, to do otherwise than count these numbers, increasing by one each time, as far as 100,000,000. To save time, he then set it ahead nearly to that point, and bade them mark the result. The numbers were shown as follows:

99,999,997,
99,999,998,
99,999,999,
100,000,000,
100,000,001, (after this the law
100,010,002, changes)
100,030,003,
100,060,004,
100,100,005,
100,150,006, etc.

The machine obeyed a new law after the 100,000,001st term, adding 10,000 times the series known as triangular numbers to the continuation of the original series. He then showed that this law would govern 2,761 terms, when a new law would come into operation; that this new law would last for about 1,430 terms, and then be succeeded by another; and so on *ad infinitum*. The machine could be set so that any of these laws would exist for any assigned number of times, and any of them might cease and reappear after any desired interval. Now, if a person knowing nothing about this engine could watch it count the natural numbers up to 100,000,001, his expectation that the next number shown would be 100,000,002 would no doubt be so strong as to amount to a feeling of certainty. Yet this expectation would be disappointed without any violation of natural law, but in such strict conformity thereto as to be foreseen by any one understanding the mechanism. So, argued Mr. Babbage, what we call a miracle may seem strange and unlikely to us only because of our ignorance, though known to the Creator of the universe to be a necessary consequence of the manner in which he has made his works. We may add that this view of miracles has been adopted by all the principal religious writers on the subject since the publication of Mr. Babbage's work.

With Mr. Babbage's minor labors, his recreations, and the "chips from his workshop," a volume might easily be filled. While yet at college, he joined with Herschel, Peacock, and others, in introducing the differential notation of Leibnitz into England in place of the less manageable fluxions of Newton. He was skilled in finding the key to writing in cipher, and, to aid him in such pastime, went to the trouble of classifying all the words in the English language, according to their lengths, the repetitions of the same letter in them, and the positions of the letters so repeated. He was fond of making automata of various sorts; for instance, to play games, the principal being that, at any given state of the game, the mechanism must make a certain move. His name is indissolubly associated in England with the broad-gauge railway, the final adoption of which was due to an elaborate series of experiments which occupied his spare time for several years, and a luminous report, in which he summed up the results of his investigations. Improvements in storm signals, in mechanism to make it difficult to counterfeit bank notes, and in the English postal system, are also due to him. His foible was a hatred of organ-grinders and other street noises. He was continually waging war with them, but the only result was to make them more and more desirous of annoying him. A much better course would have been to acquire the habit of concentrating his mind on his work so as not to be disturbed by such noises.

In conclusion, to throw some light on the workings of an inventor's mind, we will quote a remark which he made a few years ago:

"I think one of my most important guiding principles has been this—that every moment of my waking hours has always been occupied by *some train of inquiry*. The necessary training was difficult. Whenever at night I found myself sleepless, and wished to sleep, I took a subject for examination that required little mental effort, and which also had little influence on worldly affairs by its success or failure. On the other hand, when I wanted to concentrate my whole mind upon an important subject, I studied during the day all the minor accessories, and after 2 o'clock in the morning I found that repose which the nuisances of the London streets only allow from that hour until 6 o'clock in the morning."

The St. Petersburg War Office states, in an official order, that the number of breech-loaders required for the entire army on a war footing has been completed at last, and that there is also an ample supply of cartridges on hand. The rifle adopted is an improved needle-gun, called, after the manufacturer, the Krick pattern.

REMARKS ON CONCRETE BUILDING.*

By A. W. BLOMFIELD, M.A., F.R.I.B.A.

From the "English Mechanic."

In the few remarks which I have to make on this subject, I shall confine myself to the consideration of that system to which walls are constructed *in situ*, by filling concrete into cases, or moulds, made to shift to the various requisite heights and positions as the work proceeds. The system of building with blocks of concrete or artificial stone, cast separately and put together when dry, having little to distinguish it from the ordinary methods of construction, calls for no special notice.

Much misconception, now happily disappearing, was excited as to the pretensions of concrete building, and, in consequence, many absurd objections have been raised against it. As one instance among many, I may mention that, when a few years ago a paper was read on the subject at a meeting of the Architectural Association, an architect gravely objected that, though much had been said about concrete walls, nothing had been said about roofs. He considered that a building was useless without a roof, and he wanted to know how it was proposed to roof a concrete building. There seemed, in fact, to be an idea that the advocates of concrete looked upon it as a new invention destined to supersede all other methods of construction. Any one who has taken the smallest trouble to investigate the subject is, of course, aware that, like many other so-called inventions, it is merely the revival of a very old expedient, though some of the features of the machinery now generally employed are certainly new, and very ingenious, and useful. The authors of other papers will, no doubt, enter more minutely, and with more scientific details than I can, into the question of the materials and proportions proper for concrete building; I shall, therefore, say little on this point. For the same reason, coupled with a desire to be brief, I forbear to mention the numerous tests to which the material has been subjected, and the proofs of extraordinary strength and durability which have been the result. One significant fact, however, should be noticed. In using ordinary materials, no sooner is a building completed than decay commences at once, in a greater or less degree. Portland cement concrete, on the other hand, has been proved to continue to harden for a very considerable time—some say even as long as two years. As far as I can ascertain, the only cementing material to be relied on is Portland cement of the best quality, and for the other ingredients, any may be used that are usually employed in carefully composed concrete for ordinary purposes, especial care being taken that they be quite clean and free from clay or earthy particles. The proportions vary from 1 of cement, and 8, 9, or even 10 of other material for walling, to 1 of cement, and 5 or 4 of other material for lintels, steps, and flats for landings. The interior of walls of more than 4 in. in thickness may be packed with rough stone, broken bricks, chalk, or any other similar material that can be easily procured in the neighborhood.

Time will not allow me to enter into any description of the different sorts of cases and machinery now in use, and the various details, manipulation, and use of the material; but so much has been said and written on the subject, and the system has now become so common, that anything of the sort would probably be unnecessary.

The chief advantages of concrete building may be summed up in a few words: First, cheapness; secondly, strength and durability; thirdly, rapidity of construction; fourthly, economy of space.

The chief drawbacks appear to be: First, its liability to failure, from the use of improper materials, or from the want of knowledge and proper care, or from the wilful misuse of good materials; secondly, the limits which the material and method of construction impose on architectural design and decoration.

The question of cheapness depends on locality. As a rule it will be found that where bricks are the local material, concrete will be, bulk for bulk, cheaper; and, as it may be used thinner than brick with

* From the Report of the General Conference of Architects, 1871.

equal strength, and without the employment of skilled labor (except that of a foreman), the saving is usually considerable over brickwork. On the other hand, where a local stone may be obtained very cheaply, concrete will not be found to effect any saving in ordinary walling.

In respect of strength and durability, my experience has led me to put the greatest possible faith in carefully compounded Portland cement concrete. I do not think that its capabilities in the way of fire-proof flooring, without any adventitious aid of iron girders or other supports over considerable areas, has ever yet been properly tested. Its extraordinary strength when employed for walls must now be fully recognized by all who have given it a trial.

With regard to the next point, rapidity of construction, although no doubt many concrete buildings have been run up in an incredibly short space of time, I think that too much stress has been laid on this as an advantage, and I believe that some disasters which have occurred are attributable (in part at least) to undue haste. I have myself seen partial failures from this cause, which, by the subsequent hardening of the concrete, have stopped and gone no further.

Economy of space is only gained by the possibility of making walls (particularly internal division walls) thinner than in ordinary brickwork. Though this seems a small matter, it will be found that in a large establishment, with many small divisions, the saving in space covered is considerable. I now come to the drawbacks. Of these, the first speaks for itself. It is, no doubt, the most serious objection to the system, and has deterred many from giving it a fair trial. I pass it by, however, as a point which occurs to every one, in order to conclude with a few remarks on the limits imposed by this material and method of construction on architectural design and decoration.

It is, of course, possible to build plain walling in concrete, using quoins, window dressings, strings, cornices, etc., of stone; but I refer to cases in which, from economical or other motives, an architect may desire to confine nimself entirely to the use of concrete, without brick or stone. In connection with this view of the subject, I take the first opportunity of protesting against the idea of a concrete arch. Concrete is in fact a solid mass of artificial stone, and it would be as rational to scoop out the underside of a York landing or a Portland stone lintel into an arched form to increase its strength, as to mould a mass of concrete into such a shape with the same object. Concrete construction such as I have described is essentially monolithic, and the arch has no proper place in it, except perhaps as a mere decorative feature, evidently unconnected with the construction, if, indeed, such a use does not carry its own condemnation. In saying this, I do not of course refer to barrel vaults and domes which may properly be constructed as solid crusts or shells in concrete.

Wherever any architectural character or decoration has hitherto been attempted in concrete building, it has taken the form of the usual imitations of stone in Portland cement, and this has had the effect of increasing the prejudice against it as an encourager of stucco and shams. Now, Portland cement stucco, so far from being necessarily a sham, seems to me to be an admirable and useful material, which through long abuse has fallen into disrepute, but which is capable of perfectly legitimate treatment with very good results. We must not, of course, look for effects of light and shade produced by bold projections of cornices or string-courses, not for sculptured decoration; but we may get color and surface ornamentation, as, for instance, by incised, stamped, or "sgrafito" work, without the use of any other materials than concrete and cements. This is what we ought to aim at, and whatever is done, the monolithic character of the structure should be borne in mind, and nothing should be allowed to twist it into forms and appearances foreign to its nature, merely to make it look like other buildings.

For suggestions as to legitimate and artistic treatment of external plaster-work we have plenty of examples, not only abroad, but in numerous old houses in all parts of our country. Ornamentation of this kind could scarcely be so expensive as the elaborate cast imitations of stone which are usually employed.

I think, however, that in this system of building, a great deal may be done without plastering the surface, by using a fine concrete which may be kept to the external face of the work, and left untouched when the cases are removed. It is true that it is impossible, for several reasons, to avoid showing the marks of the different levels at which the cases are fixed, but this, being a necessity of the method, should be made a feature; the marks should be clearly defined, and advantage might be taken of them to vary the color and composition of the surface concrete. Finally, broken granite or quartz, fine sea-shingle, and colored sands may be suggested as materials for it.

In conclusion, without claiming for concrete building the extraordinary merits which it has been supposed to possess, I think it is a subject well worthy of the attention of architects, and one which is capable of very great development, particularly in an artistic point of view, but in this direction nothing can be done so long as the only aim is to show how well it can be made to imitate some other material and some other method of construction.

THE DESICCATION OF WOOD.

By M. A. PAYEN.

Translated Abstract from "Annales de Conservatoire."

The methods heretofore employed in the desiccation of wood may be referred to one of the following classes :

1st. Coatings applied to the surface of wood in order to prevent the contact of air and moisture.

2d. Simple immersion in an antiseptic fluid.

3d. Vital suction or filtration, of which the Boucherie process is the type.

4th. Injection of antiseptic fluids. in a closed vessel, by alternation of vacuum and pressure.

5th. Artificial desiccation followed by injection in closed vessels.

In this article we propose to describe the different processes of desiccation by means of drying ovens. It is these ovens, that we would particularly examine ; considering their mode of construction, their action, and advantages in their application either to simple desiccation or to preliminary drying to be followed by injection.

The presence of water and air in wood, is one of the principal causes of the fermentation of its organic matter and of its consequent alteration and destruction. These changes often remove an appreciable part of organic matter containing combustible carbon and hydrogen. Again the hygroscopic water contained in the wood, in its volatilization absorbs a part of the heat developed in combustion, and thus diminishes its calorific powers.

In order to give a precise notion of the utility of the desiccation of wood-fuel, we should compare the quantity of useful heat obtained from dried and from green wood. This comparison is easily made by taking for standard the mean elementary composition of some wood, say oak, and the equivalent of carbon given under the two conditions.

100 parts of dry oak contain 50 of carbon, 6.20 of hydrogen, and 43.80 of oxygen. To the calorific power of the carbon (50) should be added, the equivalent representing the excess of hydrogen (somewhat variable in different kinds of wood) above the quantity necessary to unite with the oxygen so as to form water. In oak this excess is 0.630 ; equivalent to at least 1.89 of carbon. We may therefore consider 100 parts of dry oak as equivalent to $50 + 1.89 = 51.89$ of pure carbon.

But in order to determine the quantity of useful heat, it is proper to deduce that which, in the process of combustion, transforms into vapor the hydrogen and oxygen. This water of composition is $\frac{50}{100}$ of the total weight, absorbing in transformation into vapor at the temperature of combustion a quantity of heat equivalent to 5 of carbon, which is to be deducted from 51.89 ; giving a remainder of 46.89 of useful carbon, which represents the calorific power of 100 parts of dry oak.

Now suppose that moist oak contains 45 per cent. of water : As 100 parts desiccated wood represent 46.89 of carbon, 55 would give 25.79 of carbon ; from which is to be deducted 4.50 used in vaporizing the 45 parts of water ; giving 21.29. It follows that 225 parts of green wood must be burned to give as much useful heat as 100 of dry. But besides this loss, it happens that in certain cases, as in the melting of glass and of zinc, it is impossible to attain the desired end by use of green wood. Hence, desiccation, almost always useful, becomes an absolute necessity in the manufacture of glass and in metallurgy.

In the injection of wood under pressure the elimination of the water of moisture permits the antiseptic liquid to take its place. Hence the more or less complete expulsion of the water would be useful in various ways, and would fulfil one of the conditions most favorable to its conservation.

There are two methods of desiccation: the natural, by long exposure to air, under sheds; and the artificial, by means of stoves or ovens. The natural process is insufficient for preservation. For however great the pains and long the exposure, there always remains a residuum of water, amounting to from 10 to 20 per cent.; which is sufficient to cause fermentation, to invite insects, and to favor cryptogramic growths. This sort of drying is suited only to wood for carpentry or furniture; being sufficient to prevent change of dimensions or warping when it is removed from farther action of humidity. The artificial process better assures preservation, since it can drive from the wood all the contained moisture; still this condition cannot be maintained against the influence of the atmosphere, except by some coating impervious to moisture.

On the other hand, the preparation of the wood, or its injection with antiseptic fluids by the method of close vessels (*en vase clos*) cannot be successful unless the wood has been sufficiently dried, so as to allow the withdrawal of the air from the tissues. If moist wood is subjected to this process, the liquids cannot escape; and of course their place cannot be taken by antiseptic fluids.

Experience has shown that injection *en vase clos*, is practicable only upon woods sufficiently dried, and this explains the invention of so many apparatuses of desiccation. The use of these has progressed but slowly; a fact due to their imperfection. Either the price of construction was too high, or the time necessary for desiccation was too protracted. Only within a few years has this preliminary desiccation become successful; a success due to the new apparatus to be described further on in this article.

Until these inventions were made it was necessary to leave wood (especially railroad ties) exposed to free air for 4 to 8 months before it could be worked up. This was onerous; for besides loss of interest on stock, there was expense of shedding and of transport.

Attempts to desiccate wood date from time long back. Wollaston and Fourcroy recommended the process; and Newmann employed steam for the purpose. Placing the wood in a large wooden box, he admitted steam from a boiler and drew off the condensed vapor charged with albumen and sap. The progress was tested by the color of the liquid drawn off. When this became colorless the wood was taken out. This method would have given favorable results if superheated steam had beem employed so as thoroughly to permeate the wood; but the expense would have been too great.

In 1837 M. de Mecquenem invented a process which consisted in subjecting the wood to a current of heated air in a closed vessel; the current being impelled by a blower. The air entered at the bottom and escaped at the top.

In 1839 M. Charpentier patented an invention in which he made use of a hermetically closed chamber, in which the wood was exposed to the action of air heated by passing over metallic plates, and introduced through 4 longitudinal tubes disposed upon the floor of the furnace, from which it was discharged into the heating chamber. The vapors and the moist air escaped by 4 longitudinal pipes placed in the upper part of the furnace and communicating with the chimney.

In 1848–1853 Bethell, who, as is well known, gave much attention to the preservation of wood and vegetable substances, took out a number of patents in England and France. One of these consisted of a rectangular brick chamber, with hollow walls filled with cinders to prevent radiation; the arched roof being constructed in the same way. One end was left free to admit a carriage on rails. A double iron door closed this entrance when the chamber was filled. At the other end was a furnace provided with a grate for the burning of coke, oil, wood, or tar, according to the end in view whether simple desiccation, or *smoking;* that is, impregnating with antiseptic gases proceeding from the incomplete combustion of tarry substances. The products of combustion passed through a central flue at the bottom, which biforcated near the entrance; the branches carried the smoke to the bottom of the chamber, from which it passed over the wood. The smoke and gases and moisture escaped at one end by a pipe at the top, and at the other by a sort of ventilating chimney. Bethell says the temperature should be kept at about 110 deg. Fahr. The time varied from 8 to 12 hours. This rapidity must have been at considerable expense of fuel. The rapid movement of the heated gases did not permit the complete utilization of their caloric, and it is doubtful whether large pieces of wood, as railway ties, can be thoroughly desiccated in so short a time. This indeed was shown by numerous experiments made at London in 1853 by the "Desiccating Company." The wood was placed in a close chamber of a capacity of about 1,000 cubic metres. The air was heated in Taylor's apparatus, as in the metallurgy of iron, and was driven over the wood by a ventilator; but slowly, and in such a quantity that the atmosphere of the chamber was entirely changed in 3 or 4 min. Nearly 9 hectolitres of coal was consumed in 24 hours. It was found that an average of 15 days was required for complete desiccation at a temperature of from 45 deg. to 60 deg. This low temperature and protracted time seem to be better for woods that are to be used in carpentry, cabinet work, and the like.

The furnace of M. Guibert of Tourlaville, invented in 1861, was in essential points similar to that of Bethell, patented in England in 1848.

Reuther's invention (1860) is intended for the desiccation of ties and their injection with creosote. The products of combustion are introduced by means of canals at the bottom of either side of the chamber. These are covered with iron plates which heat the air within the chamber. At the extremities near the door, are two vertical pipes which enter the hollow space in the walls and the vault. Two chimneys surmount the vault at either end.

Before the wood is put in, the two orifices at the end of the canals is opened so that the smoke and heated gas may enter the chamber and raise its temperature. At the beginning of the operation, one chimney is closed so that the products of combustion may pass directly to the other chimney by the vertical pipes. When the vault is warm enough, the second chimney, that near the entrance, is closed. The time of desiccation is 24 hours; the temperature is gradually raised to 100 deg. If the time for any reason is shorter (as 12 hours), still the temperature is constantly maintained at 100 deg. But this is not approved, as carbonization is likely to ensue.

In all the apparatus described, the gas, smoke, and heat are introduced at the bottom, while the discharge is from the top. This disposition is defective, because the heated air rises directly to the top of the chamber and escapes without having had time to become saturated with the moisture of the wood.

Peclet in his "Traité de la Chaleur," tome ii., chap. vi., noticed this defect, and recommends a reversal of disposition. He states that in 1822 M. Ternaux effected this in a vermicelli desiccator at Saint Ouen, and that the operation was much more rapid. He says: "We thus find a condition of great importance; that the issue of vapors should always be effected at the bottom of the drying-chamber. This prevents stagnation, and is at the same time very favorable to the saturation of the heated air; for hot air moves rapidly while rising in a denser medium, but moves slowly and distributes itself uniformly when it circulates downward."

Peclet proposed the following process for drying wood and peat: Two parallel galleries with a furnace at the bottom of each, and horizontal pipes under the bottom, through which the smoke is to pass uniformly and in succession, and so as to distribute the heat as uniformly as possible. Each gallery is to be closed at both ends by double doors, and is to be provided with rails for iron wagons, upon which the wood is to be piled so as nearly to fill the chamber. The smoke of the two furnaces passes into a common chimney of large section, having a draft-regulator at its top. The adjacent walls of the galleries form a closed space; in the middle of this is a chimney which communicates below with each of the galleries by means of orifices provided with registers. On each side of the chimney, at the bottom, are the furnaces.

This process was applied some years after at Graffensladen. The apparatus was of trapezoidal form ; there were 6 chambers heated by 7 furnaces ; disposed in 2 sections separated by a passage. The vapors escaped by lateral orifices at the bottom, opening into the chimneys. Each furnace was connected with a horizontal brick chamber, hermetically closed at the end, which divided and returned upon itself to open into vertical chimney near the furnace. The desiccation lasted night and day for from 10 to 20 days. Experience fixed the temperature for oak at 40 deg. and for pine at 50 deg. The action of this apparatus is very slow, and therefore not fitted for desiccation of railroad ties.

In 1851 M. Imbert took out a patent for an oven for drying wood intended as fuel, in metal or glass works. The chamber was long and its bottom was covered with metallic plates forming three longitudinal tubes which terminated at one end in the chimney of a small furnace set several metres below, in a vault. The carriages entered at one end and were removed at the other, near which the products from the fire entered by orifices in the plates. The gases escaped by an orifice in the lower part of the oven. When the wood on the carriage nearest the discharging door was dry enough, it was shoved out by another introduced at the entrance. The temperature was lower nearer the entrance, so that the wood advanced in a contrary direction to that of the motion of the gases, and passed into successively higher temperatures.

This device of making the wood advance in a direction contrary to the motion of the heated gas was afterwards recommended by Lechatelier in 1853, before the Society of Engineers. He proposed, for desiccation of ties which were to be injected, an apparatus like the kiln employed in annealing glass. The wood was to be put in a long gallery, on wagons, and to be slowly moved in a direction contrary to that of the heated gas, towards the maximum point of temperature. The introduction and removal were to be as in the last case. M. Lechatelier thought that this operation could be conducted with the greatest facility ; and that with a kiln 100 $\times$ 2 metres, 500 *steres* could be desiccated in 24 hours.

In 1863 M. Blythe, an English manufacturer, who was engaged at Bordeaux and Landes in the injection of wood with sulphate of copper, invented the apparatus which has now come into most general use. This is a double oven, composed of two rectangular chambers of clear dimensions 3.25 m. wide, 2.50 high, 3.25 long. The outer and partition walls are of brick, resting on a foundation of masonry. Two brick vaults roof the chambers. The side and partition walls are hollow, the space being 7 to 8 centm. wide, and extending the entire length and height of the wall. These hollow spaces communicate with the lower part of the chambers by small openings, and with small chimneys at the top. At either end of each chamber is a double gate of iron, or wood covered with galvanized iron. In each chamber, at a little distance from the side walls, are set two walls of masonry for the rails. Between and below these walls is a long arched passage, communicating with a furnace. The furnaces are covered by a fire-brick vault, which projects over the fire-grate far enough into the chamber to cover the flame. Along the whole length of the walls of the passage just described, and inside the rails, run two small flues or passages ; and between these is another flue, so connected with the furnaces as to form a separate passage for each, so as to prevent the mixture of the products of combustion.

The action of the apparatus is as follows : Four wagons of wood are introduced, and the doors are shut. The products of combustion enter the passages, from the furnaces ; thence they enter through orifices into the two flues just inside the rails. The heated gases now rise and pass through the wood, taking up the water that has been converted into vapor. In doing this they cool, and then pass along the walls, which are colder than the middle of the chambers. Arriving at the bottom, they escape by orifices regularly distributed into the hollow wall, and pass out the chimneys. By this method a constant and uniform circulation is assured, and the temperature is sensibly uniform.

The construction of an oven like the one just decribed, costs about 8,000 francs, and the expense for each tie, including fuel, labor, handling and interest on capital, is 0.07 fr.

M. Blythe afterwards modified his apparatus in some of its details; not affecting the general action. As the iron plates of the flues in the original oven were rapidly destroyed, he substituted hollow fire-brick.

In France 11 of Blythe's apparatus have been erected, 9 of which are still in operation.

Artificial desiccation, to be efficacious, should remove from the wood a volume of about 300 litres to the cubic metre, so as to allow the injection of an equal volume of creosote, or of a solution of sulphate of copper, at 0.02; equivalent to 6 kilogs. of crystallized; these proportions having been found sufficient for preservation. An obvious advantage of this method of desiccation is that the process can be completed within 24 hours after a tree has been cut down, and that water-logged timber can be subjected to it.

PAPER-MAKING IN JAPAN.

From the "Journal of the Society of Arts."

The art of paper-making in the country of the Mikado forms the subject of a very interesting Parliamentary document just issued, comprising reports from three of her Majesty's consuls in Japan. Mr. Lowder's report, addressed to Sir H. Parkes, from Kanagawa, was accompanied by numerous colored illustrations, the work of native artists, and costing only $4. These illustrations now accompany the report in the form of engravings, and are highly interesting, being singularly bold and graphic, conveying a very clear idea of the processes referred to.

According to Mr. Lowder, the manufacture of paper from the paper-mulberry (*Broufsonetia papyrifera*) was introduced into Japan about A. D. 610, being mainly brought about by the skill and enterprise of Shôtokn Taishi, a son of the reigning Mikado, who improved on what he had previously learned from Donchô, a priest from the Corea. This Donchô is said to have been a clever man, learned in the Chinese classics, and a skilful artist. But his paper was not all that could be desired. It did not take ink well, and it tore very easily. Taishi had recourse to the paper-mulberry, and caused it to be extensively planted all over the country, taking measures at the same time to have the mode of manufacture largely promulgated among the people. From the year 280, paper had been imported into Japan from the Corea, but soon after 610, thanks to the ingenuity of Taishi, the Japanese learned to make their own paper, and even made it of better quality than that of Corea. The art, as practised in the present day, is very rude in its appliances, but is very satisfactory in its results. The mulberry stalks, cut into lengths of 3 ft., or rather less, are steamed, and the skin thus softened is afterwards stripped off by hand. The skins thus peeled off are hung up to dry, a process which occupies from 1 to 3 days. They are tied up in bundles, and exposed to the action of running water for 12 hours, or perhaps 24. After this washing, the outer dark skin is stripped off from the inner fibre by means of a knife, the tool being held stationary with the right hand pressing on the material, which lies on a straw padding. The operator then draws the material towards him with the left hand, and as the stuff passes under the edge of the knife the outer fibre is stripped off. The dark outside skin is used for making inferior kinds of paper. After being thoroughly washed in running water, which causes it to open out flat, it is boiled. It is then allowed to rot, and is well beaten, after which paper is made of it, by admixture with the "tororo." In years when the paper-mulberry is scarce, this kind of paper is sometimes made of the common mulberry. The mode of manufacture is the same, and the leaves are occasionally made use of for the purpose.

Reverting to the treatment of the inner fibre, we observe that this is parcelled into lots of about 32 lbs. avoirdupois each. It usually takes 3 days to make this into paper, but adepts can accomplish its manufacture in 2. These parcels are taken to the river and thoroughly washed, after which they are steeped in buckets of water. The water is then run off, and heavy stones are placed upon the fibre to squeeze out the remaining liquid. The parcels are next boiled, so as to get rid of all sticky and glutinous matter, and the fibre is then called "sosori." Great care has to be taken that the boiling goes on evenly, and sometimes the boiling has to be assisted by throwing in wax-ash or common lime; but the admixture of either of these will slightly affect the color of the paper. The boiling, moreover, is not carried on by means of common water, but by the use of water in which the ashes of burnt buckwheat husks have been infused. After this boiling, the sosori undergoes a second washing, in order that the residue of the ash infusion may be thoroughly expelled. For this purpose it is placed in a basket, through which running water is allowed to percolate, after which the basket is lifted up, and the water runs off. The night before the paper is made the sosori is again washed, and the next morning it is pounded "for about as long a time as it takes to boil the rice for breakfast." When paper is made in the winter a little "tororo" is mixed with the sosori before pounding, but in spring rice-paste is used The tororo is a plant, having a root about the same size as that of the common dock. The sprouts and skin of the root are scraped off, and the root is then beaten. When required for use the "tororo" roots are boiled into a tolerably thin paste, and strained through a fine hair sieve into a tub.

In making the paper called "hanshi," the sosori is first formed into a large ball, from which lumps are broken off as required. These lumps are cast into what is called a "boat," and thoroughly mixed with well-strained tororo paste. The necessary pulpy mass is thus formed. In making "hanshi," the boat containing the pulpy material has a length of 6 ft. and a breadth of 3. A sort of tray or frame, of the requisite size, has a false bottom of plaited bamboo. This tray is dipped into the pulp, or the pulp may be poured into it. An inner frame is then fitted so as to press down on the false bottom and keep it tightly in its place. A peculiar and dexterous jerk is then given to the apparatus, which has the effect of "setting" the paper. The frame is then placed in a leaning position against an upright rest in the boat to allow the water to run off while another frame is prepared. By the time a second frame is ready, the first may be removed, and the entire manipulation is such as can be performed very quickly by experts in the manufacture. Paper made in the winter with "tororo" has the advantage over that made in the spring with rice paste, that it is not likely to become worm-eaten.

In order to dry the paper, the sheet is removed from the frame with a piece of bamboo, the thicker end of the paper being dexterously curled round the stick. By means of a brush the paper is laid on the drying-board face downward. Five sheets are placed on each side of the board, which is 6 ft. long, and each manipulator requires 40 drying-boards. In fine weather the paper drys quickly, in wet weather it is sometimes dried by the heat of a fire. Cutting is effected by a knife, applied to parcels of 100 sheets. Packing into bundles for market follows.

Mr. Annesley, writing from Nagasaki, describes the mode of making paper from the bark of the "kaji" tree, and says:—"There are no reasons why the 'kaji' tree should not flourish in England, more especially if planted in a damp soil; and when it is considered that paper could no doubt be manufactured from this bark at a cheaper rate than it could be made from rags, added to the considerable strength it can attain, and the various useful purposes to which it can be applied, the cultivation of the kaji shrub in England is well worthy of a trial." The writer adds —"Some inquiry after this bark has been made by home paper manufacturers from merchants at this port, and samples have been sent to England, where its value will no doubt be appreciated and turned to account." The many forms which paper takes in Japan seems to suggest that we are far behind in the development of this industry. The Japanese will make paper "warranted to wash." They also manufacture oil-paper for rain-coats and other purposes. Some of the common paper is made so tough that it can be torn only with difficulty. Paper is made to have the weight and hardness of heavy wood, or the lightness and elegance of net. Paper hats are made in imitation of straw, the paper being twisted, plaited, shaped, and varnished. Leather is also imitated, and these imitations have excellent qualities to recommend them. Coats, shoes, umbrellas, pocket-handkerchiefs, and numberless other articles are made from paper. As for the raw material, we are told that the Japanese are acquainted with the method of manufacturing paper from rags, but never adopt it, preferring to make their paper from the bark of trees. If the kaji tree can be successfully grown in England, our own paper-makers might find it a very useful source for a portion of their raw material. The Japanese seem to luxuriate in an abundance of "sosori;" but in this country the paper-making industry is hemmed in by a comparatively narrow circle.

This news comes from Japan very opportunely, and the document before us states that sundry samples of the material have been sent to the South Kensington Museum. The subject is not merely curious, but important. Sir H. Parkes regrets that the information afforded in the consular reports is not more complete, but says :—"It has not been found easy to obtain information from Japanese informants engaged in the trade relative to the production of the raw material or the mode of manipulation." The manufacture appears to be carried on in the interior provinces, and no opportunity of observing the process has been met with at Yeddo.

MODERN CANNON POWDER.

From "The Quarterly Journal of Science."

In the year 1799, nearly a century ago, General Sir William (then Captain) Congreve was sent to Plymouth to examine the gunpowder with which the Fleet was then supplied, on which occasion he reported that there were only 4 barrels of serviceable powder in the whole of His Majesty's ships. This state of affairs was no doubt due to the fact that the country was then entirely dependent on private manufacturers for its supply of powder, and that the proof to which it was subjected was not such as to insure its being of good quality. On discovery of the gross frauds which were thus being carried on with impunity, the Government Gunpowder Factory at Waltham Abbey was established, and,under the able superintendence of Sir W. Congreve, the quality of the powder supplied to the army and navy was greatly improved.

From this date until the general introduction of rifled guns in 1860, very little progress was made towards the development of this important manufacture, the only changes being in the direction of improvements in the preparation and purification of the ingredients, the quality of the finished powder being thereby improved, while its character remained unaltered. During the whole of this period the description of powder used with all cannon, was what is technically called "L. G.," or "Large Grain," in contradistinction to "F. G.," or "Fine Grain," which was used with small arms and muskets; but this powder was believed to be too violent for use in the rifled breech-loading guns introduced about 12 years ago, and a modified kind was therefore adopted, on the recommendation of Sir William Armstrong. The modification consisted in making the powder much larger* in the grain, and, in addition, coating it with a thin film of graphite, so as further to retard its combustion, and thus to reduce the strain upon the breech-closing mechanism of the gun.

This new powder was at first called "A_4," but its name was afterwards changed to "R.L.G.," or "Rifle Large Grain" powder, when its use was extended to both muzzle-loading and breech-loading rifled guns. Now, at the time of the introduction of this modified powder, the means of testing the action of the charge in the bore of a gun were very imperfect, and the change then made was founded almost entirely upon theoretical considerations. In order to understand these, and also the results of more modern experiments, it will be necessary to say a few words on the subject of the combustion of gunpowder.

In the first place, it must be borne in mind that gunpowder, unlike nitro-glycerine, fulminate of mercury, and other detonating substances, is not a chemical compound, but only a mechanical mixture. By the incorporating process during

* The size of grain in "L.G." powder is such, that it will pass through a sieve of 8 meshes to the inch, and be retained on one with 16 meshes, while the limits of "R.L.G." or "A_4" powder are between a 4-mesh and an 8-mesh sieve.

manufacture, the three substances of which powder is composed—saltpetre, sulphur, and charcoal—are so intimately mingled that the eye cannot detect the presence of any one of them in a free state. They are, notwithstanding, only mixed, and the saltpetre can be readily dissolved out by water, or the sulphur sublimed, in the form of vapor, by the application of a moderate heat, leaving in either case the other two ingredients chemically unchanged. The more intimate the mixture, the more nearly does gunpowder approach to a chemical compound, and the more violent is its combustion ; but there always must remain a vast difference between the most complete mechanical mixture and the most unstable chemical compound.

For this reason, the combustion of gunpowder is only very rapidly progressive, and not instantaneous, as is the case with the violent explosives mentioned above. It is this difference that renders gunpowder so valuable as a propelling agent, for, were it not for its comparatively mild action, no gun could be made sufficiently strong to resist its force. The material of the cannon would be broken before the inertia of the shot could be overcome.

Now, supposing one grain or particle alone to be ignited, it will be first inflamed over its whole surface, and the progressive combustion will take place from the exterior to the interior. Its *rate of combustion* will therefore depend upon both its shape and size, leaving out entirely for the present the question of density and hardness. A particle of spherical or cubical form will expose less surface to ignition, in proportion to its volume, than one of an elongated or flat shape, and will consequently require a longer period for the combustion of its entire mass ; the larger the particle also, the longer will be the time required for its consumption. Looking, then, at one grain of powder by itself, we may safely say that the larger it is, and the more nearly does its form approach to that of a sphere, the longer will its combustion take, and the slower will be the evolution of the gas. When, however, we come to regard the action of an aggregation of such particles, as in the charge of a gun, the *rate of ignition* of the whole charge is also affected by the size and shape of the grains. The part of the charge first ignited is that near the vent, or touch-hole, and the remainder is inflamed by contact with the heated gas generated by the combustion of this portion, so that the rate of ignition of the whole mass will be regulated by the greater or less facility with which the gas can penetrate throughout the charge, which is itself dependent upon the size and shape of the interstices between the grains. If the grains be spherical and regular in form, the interstices will be comparatively large and uniform, and the gas will penetrate the mass with facility ; again, the larger the grains, the larger the interstices between them. If, on the other hand, they be fat or flaky and irregular in shape, the passage of the gas will be more difficult, and the rate of inflammation of the charge reduced.

We see, therefore, that the considerations which affect the more or less rapid combustion of an individual grain of gunpowder also affect the rate of ignition of a charge of such grains, but in an opposite direction ; so that a form of grain which will individually burn rapidly may offer an increased resistance to the passage of the heated gas through the charge, and thereby retard its ignition, while a grain which will burn more slowly may allow of the charge being more rapidly ignited. By varying the size and shape of the grain alone, a powder may therefore be obtained a charge of which shall be ignited rapidly throughout but burn comparatively slowly, or one which shall be ignited more slowly, but when once inflamed burn very rapidly. It is necessary to draw a clear distinction between a rapidly igniting and a quickly burning powder ; this difference will be more apparent when we come to the discussion of more modern powders.

The grains in both L.G. and R.L.G. powder are very irregular in shape, and the latter is double the size of the former, so that the individual grains will burn more slowly. It was, therefore, believed on theoretical grounds that the larger powder would exert a less violent strain upon a gun, and it was adopted, as we have said, for our rifled guns, the question of *density* being regarded at that time as of minor importance, though it was already attracting some attention. It has since been conclusively proved by experiments that the *density* and *hardness* of the grains of powder are of quite as vital importance as their size and form, in determining the rate of ignition and combustion of a charge.

The density depends on the amount of pressure to which the powder meal has been subjected during manufacture, while the hardness is greatly affected by the amount of moisture present in the meal when pressed ; one term applies to the mass, while the other refers more particularly to the surface of the grains. A dense powder may be generally stated to be a slow-burning powder, while a hard one is slow lighting. Density retards the combustion, both because there is more matter in the same volume, and consequently more powder to be consumed in proportion to the ignited surface of the grain, and also because the heated gas finds greater difficulty in penetrating the solid mass of the grain. A hard powder need not of necessity be very dense; it is even possible, by pressing it in a moist state, to obtain a very hard powder which shall at the same time be lighted and porous in the interior of the grains. Such is the Russian prismatic powder (of which more hereafter), and it may be taken as a good specimen of a slow lighting but quick burning powder.

With the improved appliances now used in testing powder, the quality of the large stock of L.G. and R.L.G. in store in this country has been found to be very variable, principally due to variation in the density of different brands. Previous to the year 1868, the proof to which all cannon powders were subjected was very imperfect, and failed utterly in insuring uniformity in those passed into the service. The density was only roughly ascertained by the process of "cubing," as it was called, while the strength and uniformity of the powder was tested by the "Mortar Eprouvette." "Cubing" consisted in weighing a cubic foot of the powder, a box made to hold that amount being filled by pouring the substance loosely into it ; the weight therefore depended, to a great extent, upon the closeness with which the powder packed itself, as well as upon the absolute density of the grains. The shape of the grains, and the amount of glaze the powder has received, affect the closeness with which it packs itself, and would therefore lead to errors in determining the density in this way. At the present time the density is accurately arrived at, by means of a mercury densimeter, in which the weight of a given volume of powder is compared with that of an equal volume of mercury; the density of mercury (corrected according to the readings of a barometer and thermometer at the time) being known, that of the powder is easily calculated.

In the "Mortar Eprouvette" a round shot, weighing 68 lbs., was fired from an 8-inch mortar with a charge of from 2 to 3 oz. of the powder under examination, and the range of the shot from the muzzle of the mortar was measured. The greater the range the better was the powder believed to be, the only limit being a low one. The fallacy of this belief was proved beyond a doubt as early as the year 1864, by comparing the velocity of shot fired with different powders, by means of the accurate instruments then generally in use for that purpose. It was then found that powders which gave the best results in very small charges fired from a mortar were often very inferior when fired in comparatively large charges from guns, and the immediate adoption of a new proof of powder, by measuring the velocity of shot fired under service conditions, was strongly recommended. This recommendation was not, however, carried out until four years later, when Colonel Younghusband, the present Superintendent of the Government Gunpowder Works at Waltham Abbey, introduced the velocity proof which is now in force. The instrument used at Waltham Abbey for measuring the velocity of a shot is an electroballistic chronoscope, invented by Captain Le Bouleugé, of the Belgian Artillery, which surpasses all similar instruments in simplicity and facility of manipulation, though the principle upon which it acts is the same as in others. In it electricity is employed to record the exact instant at which the shot passes two points at a known distance apart, a short space in front of the gun. From this the time occupied by the shot in traversing the distance between these two points is known, and the velocity with which it is moving is readily ascertained, and affords a direct indication of the strength and uniformity of the powder. Every kind of powder now passed into the service is subjected to this proof, in addition to being tested by the mercury densimeter.

We have stated that R. L. G. powder was adopted in 1860 for our breech-loading guns, and that its use was afterwards extended to the charges of all rifled guns.

When, however, the size of our heavy ordnance was increased more and more, it soon became apparent that even this powder was totally unfit for the large charges then used, and its violent action earned for it abroad the unenviable *sobriquet* of "*poudre brutale.*"

In the year 1858 the gunpowder question was referred to a committee, composed of the Superintendent of the Royal Gunpowder Factory, the Superintendent of the Royal Laboratory, and the Chemist to the War Department, and it was, in fact, some of the earlier experiments of this committee that led to the introduction of A_4 or R. L. G. powder. The means at their disposal for determining the manner of combustion, and the pressure exerted upon the gun by different kinds of powder, were very limited. Nevertheless, the conclusions they arrived at, as set forth in their reports of 1859 and 1866, were very correct, and have been entirely corroborated by subsequent researches. As early as 1860 they had satisfactorily proved that the density and hardness of powder exercise an important influence on its character, and in all their subsequent experiments these points were strictly attended to. In their final report (1866) they recommended the adoption of a cylindrical "Pellet" powder of a density between 1.492 and 1.50, but pressed comparatively wet, so that, though light, the powder should be rather hard. This powder was adopted entirely upon experiments carried on with various natures of Armstrong breech-loading guns and smooth-bored mortars, and it is evident that a light, but hard, powder, such as this is, which would be slow lighting but quick burning, would be exactly suited to breech-loading guns, in which the initial resistance of the tight-fitting, lead-coated projectile is very great, as the lead has to be bodily forced forward into the grooves of the rifling.

The pellet form was recommended principally as a convenient method of making a large grain powder of considerable uniformity in size and density; but the committee did not consider that the subject of gunpowder had been exhausted by them, and closed their report with a recommendation that "systematic artillery experiments should be instituted with this pellet powder, of a sufficiently comprehensive character to test thoroughly the system."

In the meantime, while the labors of the committee were still progressing, other experiments were being carried on in this country. In 1863–4 a proposal was made to press granulated powder into discs the size of the bore of the gun, and perforated with holes to facilitate the passage of the gas. These discs varied in thickness from 2 to 3 in., and were made of powder of various-sized grains, the amount of the compressing force differing in different specimens. The results of these trials were not sufficiently satisfactory to lead to the adoption of this form of powder. About the same time a similar description of powder, proposed by Dr. Doremus, an American, was tried unsuccessfully, both in America and in this country; and again, in 1866, discs—made by compressing the powder meal—gave even less satisfactory results.

The Americans, about this period, introduced an irregular large grain powder, which they called "Mammoth," and still use in the large charges fired from their enormous cast-iron smooth-bored guns, to which they obstinately adhered for years after the remainder of the civilized world had been armed with rifled ordnance of wrought-iron or steel. The size of this powder ranges from 0.15 in. to 0.30 in. and its density is very moderate, being 1.70 to 1. 75.

"Prismatic" powder appears, also, to have been tried in America in 1865 ; it had already been fired with good results from the heavy steel breech-loading guns which the Russians and Prussians have obtained from Messrs. Krupp, of Essen. This powder is shown at Fig. 2, Plate I., being made in the form of regular hexagonal prisms about 1 in. thick and 0.8 in. in the side, perforated with 7 holes about 0.1 in. in diameter. In making up charges of this powder, the prisms are built up regularly in the cartridge bags, like honeycomb, which are then tightly tied at the mouth, so that the grains are kept firmly in their place. The perforations thus form long tubes through the charge, by which the gas permeates the whole mass.

The powder meal is pressed into the shape of these prisms in a very moist state, but the pressure is not great, as the density of the finished powder is only 1.67. The surface is, however, very hard, and being, to a certain extent, covered with a film of saltpetre, which is deposited by the moisture when the powder is dried, it is comparatively difficult to ignite; when once inflamed it burns very rapidly, being light and porous, and in this respect is very like the pellet powder recommended in 1866, being particularly suitable for breech-loading guns. Though this pellet powder was decidedly a step in the right direction, as the strain upon our guns was considerably reduced by its use, it was only nominally adopted into the service in 1867, and was never issued either to our ships or batteries. The reason for this was, that there existed no machinery for manufacturing a sufficient supply, and, while the necessary machinery was in preparation, the results of the experiments of the present Committee on Explosives led to its abandonment in favor of "pebble" powder.

This committee was appointed in May, 1869, to inquire generally into the value of various explosive substances, such as gun-cotton, nitro-glycerine, etc., in use, or proposed, for military purposes, and more particularly into the powder question, in which, through mismanagement rather than ignorance, we had fallen behind the rest of Europe. They at once entered on an extended series of experiments, with a view to the "determination of the description of gunpowder whose employment in large charges is attended with the least risk of overstraining the heavy guns" we now employ, and have rendered two preliminary reports on this subject*. From these it appears that no less than 40 descriptions of British and foreign powders have been fired in large charges from heavy guns, out of which number 4 varieties were selected for further experiments.

The guns used in these experiments are an 8-in. wrought-iron smooth bore of $6\frac{1}{2}$ tons, and a 10-in. gun of 18 tons; the latter was first used as a smooth bore, and afterwards rifled.

The means employed by the committee, in the investigation of the action of the large charges fired from these guns, are very ingenious, and may be briefly described as follows:

1. The determination of the time taken by a projectile in traversing various intervals within the bore of the gun, which was effected by means of a chronoscope invented by Capt. A. Noble, a member of the committee, and made at the Elswick Ordnance Company's Works. This will be described hereafter.

2. The determination of the pressure directly, by means of Rodman's pressure-gauge fitting on the exterior of the gun, and communicating with the interior of the bore by means of a hollow screw-plug.

3. The determination of the pressure directly, by means of an inner gauge termed a "crusher," which was designed by the committee to overcome certain defects inherent in the Rodman gauge.

4. The determination of the velocity of the projectile after leaving the gun, by means of Navez-Leur's or Le Boulengé's electro-ballistic apparatus, commonly used for this purpose.

The principle of action of the chronoscope consists in registering, by means of electric currents, upon a recording surface, travelling at a uniform and very high speed, the precise instant at which a shot passes certain defined points in the bore. The instrument may be divided into two portions: the one consisting of the mechanical arrangement for obtaining the necessary speed, and keeping that speed uniform; the other forming the electrical recording arrangement.

The first consists of a series of thin metal discs, each 36 in. in circumference, fixed at intervals upon a horizontal shaft, which is driven at a high speed by a heavy weight, arranged according to a plan originally proposed by Huyghens, through a train of gearing multiplying 625 times. The driving weight is continually wound up during the experiment by means of the handle, and the requisite speed is obtained by accelerating the motion by the handle. The precise rate at which the discs are moving is ascertained by the stop-cock, which can, at pleasure, be connected, or disconnected, with the

* "Preliminary Report of the Committee on Explosive Substances": printed at the War Office, February, 1870; and Progress Report of the same, January, 1871.

revolving shaft, and the time of making any number of revolutions of this shaft can be recorded with accuracy to the $\frac{1}{10}$ part of a second.

The speed attained is generally about 1,000 in. per second linear velocity at the circumference of the revolving discs, so that each inch represents the 1-1,000th part of a second, and, as the inch is subdivided by the vernier, into a thousand parts, a linear representation is thus obtained at the circumference of the discs of intervals of time as minute as the *one-millionth part of a second.* As a small variation in speed would affect the relations between the several records obtained, the uniformity of rotation is ascertained, on each occasion of experiment, by 3 observations—one immediately before, one during, and one immediately after the experiment, the mean of the 3 observations being taken as the average speed. The accuracy of the workmanship in the instrument is shown by the great degree of uniformity at which the speed is maintained. The Report gives the observations in 6 consecutive rounds; in 2 of these the speed was absolutely uniform, while the greatest variation in any round is as follows:

1st observation.	625 revs.	made	in	21.2	secs.
2d	"	"	"	20.9	"
3d	"	"	"	20.7	"

The arrangement for obtaining the electrical records is as follows:—The edges of the discs are covered with a strip of white paper, and each is connected with one of the secondary wires of an induction coil. The secondary wire, carefully insulated, is brought to a discharger, opposite the edge of its corresponding disc, and is fixed so as to be just clear of the latter. The surface of the paper on the discs is coated with lamp-black, so that the passage of a spark from the discharge to the disc burns away the black, and marks the spot perforated by exposure of the white paper beneath.

In order to connect the primary wires of the induction coils with the bore of the gun, so that they may be cut by the shot in its passage, the gun has been tapped in a number of places for the reception of hollow steel plugs, carrying at the end next the bore a cutter which projects slightly into the bore. This cutter is held in position by the primary wire, which is carefully insulated and passed down the plug, through the cutter, and back out of the plug, the ends being connected to the main wires leading to the induction coils. When the shot reaches the point where a plug is screwed in, it presses the cutter in flush with the bore, and, by so doing, cuts the primary circuit, thereby causing an induced spark to pass from one of the dischargers to the corresponding disc. As each plug is reached, a spark is delivered on the disc in connection with it, and thus the passage of the shot up the bore is recorded at regular intervals. By means of the micrometer, v, the distance between the sparks on the discs is read off, each spot being brought in succession exactly opposite the discharger belonging to the disc it is on; the speed at which the discs are moving being known, the time occupied by the shot in passing from one point to another is readily ascertained, and its velocity of translation calculated.

In order to test the accuracy of the instrument, it is only necessary to cut the whole of the primary wires simultaneously, when the whole of the sparks should be in one straight line, and the deviations from a straight line, that is, from an absolutely simultaneous record, give the instrumental errors.

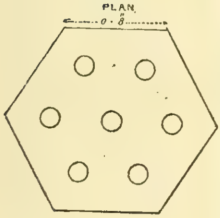
Great difficulties were experienced in securing a simultaneous rupture of the primary wires, and only two methods were found at all satisfactory. One arrangement was to cut the wires by a flat-headed bullet fired from a rifle, across the muzzle of which they were all tightly stretched; in the other they were all wound round a detonating fuze, the explosion of which severed them almost instantaneously. A number of the observations thus obtained are given in the Report, and the errors—including those due to the impossibility of obtaining an absolutely instantaneous rupture of all the wires—seldom exceed 0.000003 sec., while the maximum error is only 0.00002 sec.!

In addition to the holes tapped to receive the cutting-plugs already described, the gun is also bored to take a number of Rodman or "crusher" gauges. When any of these holes, which are 21 in number, were not required in the experiments, they were filled with solid steel plugs. The Rodman pressure gauge consists of a piston, working in a hollow screw plug open to the bore, the outer end of which carries a pointed knife, against which a piece of copper is placed. When the gun is fired, the gaseous pressure on the base of the piston forces the knife into the copper, and the indent is a measure of the pressure which has acted on the base of the plug. In this instrument the gas has a considerable space to travel between the powder chamber and the piston; thus, before reaching the latter it attains a high *vis viva*, especially in quick burning powders, and acts upon the piston more like a blow than a pressure, and the records are therefore much higher than should be the case.

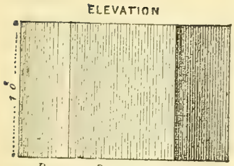
To remedy this defect the "crusher" gauge was devised by the Committee (see Fig. 3): the reduced dimensions of this instrument allow it to be placed so close to the bore of the gun that the gas has no space to travel before reaching the piston. It consists of a screw-plug of steel, having a movable base which admits of the insertion of a small copper cylinder, B. One end of this cylinder rests against an anvil, A, while the other is acted upon by a movable piston, C, which is kept tight against the cylinder by the spring, *i*. The cylinder is retained in the centre of the chamber, *c, d, e, f*, by a small watch-spring.

Fig. 2

PLAN

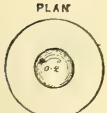


ELEVATION



Russian Prismatic Powder (full size)

PLAN



Pellet Powder (full size)

Fig. 3.

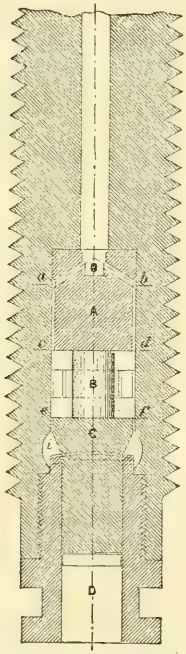
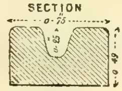
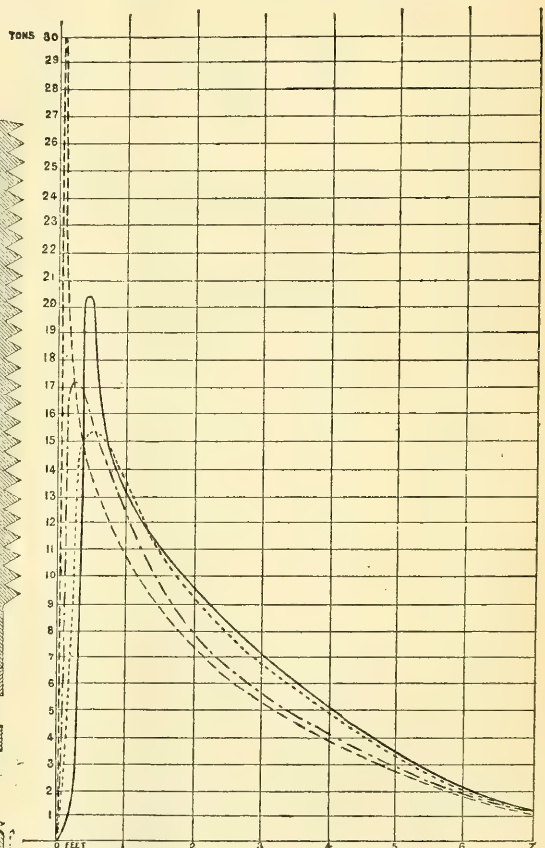


Fig. 1

SECTION





A gas-check, D, is inserted against the lower extremity of the piston, and should any gas get past this there are passages by which it can escape into the open air. Upon the explosion of the charge the gas, acting on the area of the piston, crushes the copper against the anvil, and, the amount of pressure required to produce a definite amount of compression of the copper having been determined by previous experiments, the pressure on the piston is at once ascertained. The area of the copper cylinders used in the 8-in. gun was 1-12th of a square inch, and that of the piston 1-6th of a square inch.

We have stated that 4 varieties of powders were chosen out of a large number for further experiment: these were—R. L.G. service powder, pellet service powder, Russian prismatic powder, and "pebble" powder No. 5. When fired from the 8 in. gun, in charges which best suited each kind of powder, the following results were obtained:—

Nature of Powder.	Charge.	Muzzle Velocity.	Maximu Pressure.
	Lbs.	Feet.	Tons.
R L. O.	30	1324	29.8
Russian Prismatic ..	32	1366	20 5
Service pellet.	30	1338	17.4
Pebble No. 5........	35	1374	15 4

From this table it is evident that the Service R.L.G. is far inferior to all the others, while the pebble is manifestly the best.

"Pebble" powder, so called from its resemblance to small black pebbles, was first tried in Belgium, but the powder which gave the above satisfactory results is an improvement on the foreign powder, being more uniform in size and density. It consists of irregular cubes, having edges from 5-8ths to 4-8ths in. in length, made by cutting up the "press-cake" into the required form; the powder is as usual glazed in a revolving barrel, which operation removes the sharp edges. Its manufacture is therefore very simple, little or no new machinery is required for its production, and it is cheaper than any of the other descriptions. Its density is high, about 1.8, but owing to its large size and comparatively uneven surface it is a quick lighting powder: the whole charge (if of the proper form) is quickly and uniformly lighted, and the maximum pressure in the powder chamber is consequently even throughout its surface, while with powders which are both quick lighting and quick burning, like the old L.G. and R. L.G., intense local pressures, varying in different parts of the chamber, are produced. As an example of this the following results obtained in the 10 in. gun in its smooth bore state are given.

Powder and Charge.	Rounds.	Muzzle Velocity.	Pressure per Square inch by Crusher Gauge at.		
			A. Axis of Bore.	B Centre of Charge.	C. Front of Charge.
		Feet.	Tons.	Tons.	Tons.
L. G. 60 lbs....	6	1273	49	28	29
Pellet 64 lbs.....................	3	1377	21½	21	21
Pebble 70 lbs.......	6	1435	22	22	23

The explanation of these local pressures caused by quick burning powders is very clearly stated by Captain A. Noble, in a paper read at the Royal Institution, on the "Tension of Fired Gunpowder," and may be expressed briefly as follows:—The products of combustion of the first portion of the powder inflamed, in travelling from one end of the chamber to the other, attain a very high velocity before meeting with any resistance, and the reconversion of the *vis viva* thus acquired into pressure at the base of the shot and the end of the bore, gives rise to the intense local pressures at those points, while the rapidity of combustion of the powder at that part of the charge is probably enormously accelerated by the tension under which it is exploded. "The time during which these abnormal pressures are kept up must be exceedingly minute, even when compared with the infinitesimal times we are considering; for we find the chronoscope pressure, which may be regarded as representing the mean of pressures of a violent oscillatory character, hardly altered at all, even although the local pressures are increased 50 per cent.

In the figure a representation is given of the pressure curves calculated from the chronoscope observations, and in the following table the pressures in tons shown by the crusher gauge are compared with those obtained by the chronoscope in the 10 in. gun.

CHARGE.	Muzzle Velocity.	Total Work on Shot.	Pressure per Square Inch at															
			A.		B.		C.		Mean of B and C.		1.		4.		10.		14.	
			By Gauge.	By Chronoscope.	By Gauge.	By Chronoscope.	By Gauge.	By Chronoscope.	By Gauge.	By Chronoscope.	By Gauge.	By Chronoscope.	By Gauge.	By Chronoscope.	By Gauge.	By Chronoscope.	By Gauge.	By Chronoscope.
R. L. G.—60 lbs. D 1.742........	1327	4824	51.4	..	32 5	..	26.3	..	29.4	24.3	..	10.5	12.4	8.9	4 8	6.5	3.2	4 5
Pellet—64 lbs. D. 1.677	1374	5164	25 0	..	22.9	..	20.1	..	21.5	22.2	..	10.4	11.2	9.0	5 2	6.3	..	4 3
Prismatic—61 lbs............... ..	1344	4947	18.9	..	17.7	..	18.0	..	17.9	19.3	14.7	12.3	12.0	9.9	7 0	7.0	3 7	4.9
W. A. Pebble—70 lbs. D. 1.782...	1442	5384	20.9	..	21.3	..	20.0	..	20.7	21.9	16.0	13.5	12.2	11 4	9.0	8.2	4.0	5.0

The letters and numbers refer to the plugs, reading from breech to muzzle, and it is evident that, with the mild kinds of powder, the mean maximum pressure in the powder chamber, and also the pressure at different parts of the gun, arrived at by these two perfectly different methods of observation, agree very closely; while the intense local, or wave, action of the violent R.L.G. is also very apparent. The intensity of this local action depends, moreover, in a great measure upon the length of the cartridge; if this be excessive, these objectionable strains at once begin to appear even in the case of pellet or pebble powder, as has been clearly demonstrated in the 11.6-in. 35-ton gun, firing 120 and 130 lbs. of powder, and also in the 10-in. gun when tried with proof-charges of 87.5 lbs.

The specification upon which pebble powder is received from the trade is very strict. Not only must the powder be very uniform in size and density of grain, but it is also further tested by firing battering charges (35 lbs.) of every supply from an 8-in. gun, when the pressure in any part of the powder chamber must not exceed 20 tons on the sq. in., and the variations in velocity must be comprised within narrow limits. By thus severely testing the whole of our supply of this new powder, the committee are able to insure that it shall never depart in any important degree from the required standard. The admirable results obtained in the 8-in. and 10-in. guns with pebble powder have been maintained in all the heavier natures, insomuch that the use of this powder, while materially reducing the strain upon the guns below that caused by R.L.G., has at the same time augmented their power to a very considerable extent, as shown in the following table:

Nature of Gun.	Charge, lbs.		Mean Pressure per Square Inch in Powder Chamber.		Muzzle Velocity.		Total Energy of Shot.	
	R. L. G.	Pebble.	R. L. G.	Pebble.	R. L. G.	Pebble.	R. L. G.	Pebble.
	Lbs.	Lbs.	Tons.	Tons.	Feet.	Feet.	Ft.-tons.	Ft.-tons
12 in., 25 tons... ...	67	85	23	19	1180	1300	5793	7030
10 " 18 "	60	70	32	23	1298	1364	4693	5160
9 " 12 "	43	50	21	15	1336	1420	3094	3496
8 " 9 "	30	35	30	20	1363	1413	2319	2492
7 " 6⅛"	22	30	17	10	1430	1525	1631	1855

With this, the result of the experiments of the last fourteen years, we will leave the subject, though there are many other points of scientific and practical interest to artillerymen which have been set at rest by the committee's researches, while there are others which they are at the present moment investigating.

At one period, as we have already stated, this country was allowed to fall behind some foreign nations in the all-important question of powder for heavy guns, and the capabilities of our magnificent Naval Ordnance were sacrificed, and their endurance endangered, by the use of a variable and violent powder. All this has now been set right, and it is satisfactory to feel that our ships and forts are not only armed with the best guns in existence, but that they are also being rapidly supplied with a powder in every respect suitable for their use.

A DECADE OF STEAM ROAD-ROLLING IN PARIS.

From "The Engineer."

That great improvement in ordinary macadamization, consisting in rolling the layers of broken stone by heavy steam rollers, is now making comparatively rapid headway in England. The process is attracting such attention that a valuable paper on the subject, contributed by a French company, Messrs. Gellerat and Co., of Paris, which has given the initiative, will be studied with interest by many. The municipalities of Liverpool, Glasgow, Manchester, Leeds, Sheffield, and Maidstone, and others, now possess and use steam road-rollers, and the process has already been tried on a more or less extensive scale in at the very least 7 metropolitan districts.

THE CONTRACT WITH THE CITY OF PARIS.

As long ago as 1860 experiments in road-rolling by steam engines were made in Paris. These experiments, again taken up in 1864, and continued by Messrs. Gellerat and Co., induced, in consequence of comparative trials between horse road-rolling and steam road-rolling, the engineers employed by the Paris municipality to conclude, in 1865, a contract with the company. This has given both extension and a regular and permanent character to the application of this process. The contract, made for 6 years, obliges the company to keep permanently at the disposal of the city of Paris 7 steam road-rollers of the construction patented by them. These rollers are principally intended for rolling the macadamized roads of Paris and of the Bois de Boulogne and Bois de Vincennes ; but they can also be used for setting paving stones and for rolling the foundations of paved roads. The contract fixes the maximum and minimum diameters of the 2 carrying rollers of each engine, the maximum width of the machine, the speed of travel of the engines, and the weight per metre run of the width of the external diameter of the carrying rollers. The work done is paid in the compound ratios of the distance traversed by the engine at work on broken stone to be rolled, and of the weight of the engine itself. The unit of the accounts is the kilometric-tonne ; that is to say, 1,000 kilogrammes of the weight of the engine carried a distance of 1,000 metres. This unit is paid for at the rate of 0.50 f. during the night and 0.45 f. during the day. As regards the average weight of the engines, it is determined by weighing, checked by both parties to the contract, and the distance passed over is given by a counter driven off the rollers.

THE DISTINCTIVE CHARACTER OF THE PARISIAN STEAM-ROLLERS.

The distinctive qualities of the rolling engines employed in Paris are :—The entire utilization, for the progression of the machine, of its weight; and the identity of the front and hind parts of the engine—an identity which allows it to work with the same ease in both directions, and, consequently, to advance in either direction without turning round. The 2 carrying rollers are both drivers, and are propelled in the same way, but separately, by the steam engine. We have to add that the engines can turn in a minimum radius of from 10 to 15 metres—32 ft. to 48 ft.—according to their dimensions. Thus, with their power of going either backwards or forwards, this allows them to work in the most narrow streets and to pass the sharpest corners. The application of the whole weight for obtaining adhesion gives the Gellerat Company's engine great traction power, a power often entirely called into play, especially when the metalling is of bad quality and the foundation of a yielding nature. A steam road-roller without this power would often be incapable of moving itself on freshly laid metalling, and, *a fortiori*, of dragging itself out of the many difficult positions to be encountered in making new roads. The average weights of the Gellerat engines, in the order in which they are used, are 17, 34, and 30 tonnes of 1,000 kilogrammes—in English weights, 16 tons 14 cwt. 2.5 qr.; 25 tons 12 cwt. and 1.6 qr.. and 29 tons 10 cwt. and 2.094 qr. respectively. The weights per metre run of the rollers are 6,000 kilogrammes for the smallest engines, and 8,000 kilogrammes for the two other sizes. Engines of these graduated sizes have been able to execute all the work which has offered itself up to this day. The lighter engines are more particularly suited for new work under difficult conditions; the heavier rollers, which can also be used on new work, are more suited for maintaining roads. They can roll in a single night a very considerable road surface. The maximum speed with which the engines are to work has been fixed at 4 kilometres, or 2 miles 854.5 yards per hour. This speed, but seldom attained, is still less commonly exceeded. We may estimate, as a general rule, the speed of 3 kilometres, or 1 mile 1,520 yards per hour as the average velocity developed from the beginning to the end of an ordinary day's work. Rather less at the beginning, when the draught is considerable, it increases with the degree the binding of the road approaches completion.

WORK DONE IN PARIS.

Since 1866 there has been steam-rolled in Paris a total volume of 32,000 cubic metres, or 41,857 cubic yards of metalling of different kinds, such as flints, gravel, broken stones, more or less hard millstone grit, porphyry, and trap—the last a metamorphic quartz rock. These different materials are all rolled in the same way, with slight differences depending on the manner they behave under the action of the rollers. Pebbles and gravel, which at the outset are very movable under the rollers, form a wave in its front. A small quantity of water is sometimes sufficient to diminish this tendency; pebbles bind easily with the addition of sand. These last materials are cheaper than those generally used in Paris, but they are much employed for keeping up roads subjected to considerable traffic. Millstone grit, still more binding than the preceding materials, is easily rolled, and affords an easy draught and ready maintenance. Porphyry and trap, being much harder, require to be longer rolled. The crushing together of the materials is slower, and the binding more difficult; but when this double result is obtained the road offers a considerable resistance. On these materials the heavier engines are particularly efficacious.

NUMBER OF KILOMETRIC TONNES REQUIRED FOR STEAM ROAD-ROLLING.

It results from observations made since 1866 that, on an average, 6 kilometric tonnes are employed in Paris to roll one cubic metre of any material of whatever kind. The amount of load varies according to circumstances, from 3 tonnes, and even $2\frac{1}{2}$ tonnes, up to 20 and 30 tonnes. The necessity for the latter large amounts can only be explained by a bad management of the operation, and principally by the circumstance that an insufficient amount of work is sometimes given to the engines for rolling, from which it follows that the later hours of the operation are badly or not at all utilized. It is now recognized that when the operation is well conducted it is possible to do excellent rolling with an expenditure, at the most, of from 4 to 5 kilometric tonnes per cubic metre rolled. Any little deviations are to be explained by the state of the weather, by the greater or less quantity of the matters of aggregation employed, by more or less irregularity in the watering—in one word, by the mode of working. But neither the nature of the materials nor the thickness of the layer seems to exercise a sensible influence on the result, if the rolling of one cubic metre be taken as the unit of the work done.

HOW THE OPERATION SHOULD BE CONDUCTED.

It is necessary to make a distinction between rolling new roads and rolling fresh layers on old roads. New roads constructed after the clearing away of old houses, as has been so much the case in Paris, are difficult to roll. They pass over old cellars filled up with rubbish; and the subsidences, which would in any case be very unequal, are particularly so when the filling up operations are not very carefully done, or when substances non-homogeneous, or of bad quality, as often happens in Paris, are used. It is then that the smaller form of engine is employed with advantage; it presses with less force on the ground and runs less chance of sinking down. The foundations of new roads are also often rolled. This is sometimes done in two layers, rolled one after the other, and in some cases only one layer. The first plan is by preference employed when the first layer is formed of less resisting materials; the second when the road is homogeneous. These different operations generally proceed with ease, provided care has been taken not to water too much at the beginning in order not to excessively soften the soil. The rules to be followed for watering, sanding, and rolling, do not much differ from those applicable to fresh coatings of metalling on old road surfaces. Fresh coatings used to be and still are put down principally during the rainy weather of the spring and autumn. Now that water is taken over all Paris, roads can be coated afresh, and rolled the year round, excepting during frost or seasons of great drought. When any road has arrived at such a degree of deterioration as to require a fresh coating of metalling, the surface, if the weather is not wet, is softened by abundantly watering. The picking up is then proceeded with. This consists in picking up by means of pickaxes the beaten crust of the road in order to permit the layer of fresh materials to closely bind itself with the existing old surface. The work of picking up varies with the hardness of the materials comprising the old road. It is often done by the piece. Each man takes a surface of from 20 to 30 metres—24 to 35 square yards—to pick up during a day or night. The work of picking up is hence very dear, and is accordingly often dispensed with. The workman first of all cuts transverse furrows from 0.15 to 0.20—about 5 to 7 in. distant from each other, and then picks up the road by means of smaller furrows perpendicular to the first.

The picking up being completed, the materials are brought in carts and discharged on the road, in such wise as to be equally spread over it with the least possible labor by means of the shovel. The workman then takes the stone from the heaps and spreads it over the required spots, regulating the thickness according to given gauges. An experienced man can spread as much as 10 cubic metres—13 cubic yards—of materials per day. It is also a good thing to have one or several workmen to bring back the stones that the traffic may chance to carry away on to the sides of the road. From distance to distance the whole length of the road, and on both sides, small heaps of sand are so disposed that the sanding can be quickly and equally done. In many cases the road is watered before beginning the operation of rolling; but this watering is not always carried out. Other arrangements adopted by the different employés charged with carrying out the operation of rolling, such as the more or less abundance, and the succession of subsequent waterings, the spreading of the sand at the successive stages in which the road gets bound, are exceedingly variable, and it would be extremely difficult to prescribe any absolute rule. In this operation, as in all others of the kind, there is a certain knack, difficult to describe, but which is pretty easily acquired, and which is not so strictly fixed as to prevent one reaching the goal by different ways. The only secret in managing the work when the sand is of good quality is to attentively follow the binding of the broken stone, and to slacken or increase the watering and spreading of the sand on the parts where the rolling engine is at work.

The quantity of water to be used is very variable, being dependent, as reflection will at once show, on the weather. It would be difficult to give a strict rule for its use. Avoid using too much, especially at the beginning of the work, in order not to drown the bottoming in the course of the operation; use sufficient water to make the stone and sand slightly moist; and towards the end, when the broken stone is bound, and the moisture appears at the surface without penetrating to the interior, abundantly water the road in order to carry off any sand in excess and that to obtain the final smoothness of the surface. Such are nearly all the general directions that can be given. As regards the hogging or sand used for binding, that applied in Paris generally comes off the road itself, and it is also the best.

It must have binding properties without being clayey; the cleaner it is the better, provided it is not too sharp. The road laborers (*cantonniers*) obtain it by washing the mud of the road. As to the quantity that should be employed in order to make the best rolled road, this also greatly varies in practice. Some throw the gravel on from the beginning rather plentifully, others only begin to use it when the stones are already squeezed together. On the first introduction of macadamized roads the stones were prescribed to be absolutely clean, and the use of any detritus was severely prohibited. This idea has not been adhered to. But generally it can be said that it is better to sin in the direction of too little than of too much binding, and the general tendency in Paris is to reduce the use of binding materials to the lowest quantity possible. Let us merely add that, as regards both sand and water, there is no inconvenience towards the end of the operation, when the binding has taken place, in applying much sand or water respectively during the last passages of the roller. Any excess of sand is carried off by the water.

THE MANAGEMENT OF THE STEAM-ROLLER.

The working of the engine remains to be spoken of. We are here confronted by a rule which is never departed from, whether as regards a road being rolled along its whole breadth, or only half its breadth, though it principally relates to the case in which the whole width is being rolled. The operation is always begun at the sides. The roller at first executes a certain number of passages over one of the edges of the macadam. When the stones begin to be brought together the surface is slightly watered from a barrel or by a jet, and by means of a spade a very thin layer of the sand provided is spread. At each passage the roller is gradually brought nearer to the crown of the road. The operation is continued in this way for some time, and when the one side of the road is sufficiently bound the other is begun with, and brought to the same state as the first. The central part is done last and in the same mode. The roller thus passes over the whole surface, staying longer over those portions less squeezed together than the others. During the operation the road is moderately sanded and watered. As we have said, towards the end the excess of water runs to the surface, taking with it also any excess of binding material. The rollers then produce no impression. By this means a smooth hard road is obtained, and it can be at once open to traffic. The heaviest carts leave no trace.

THE ECONOMY THROUGH STEAM ROAD-ROLLING.

Since the steam roller has been used in Paris the bottoms of the roads have been improved and the duration of the surfaces has much increased. Some roads which, when steam rolling was first employed, were covered with fresh metalling and rolled every 6 months, are now rolled only once a year. This proves a very great economy in the metalling. Steam road-rolling is done in a much shorter time compared with that required for horse road-rolling. It thereby much diminishes the labor required in the necessary operations of watering, sanding, and managing the work. At the same time it prevents the considerable losses produced by the stoppage or the delay of the traffic. This stoppage is otherwise always considerable, whether the stone be spread without rolling it, or whether it is rolled with horses. This loss represents, even without there being very much traffic, a considerable sum. With steam road-rolling, which is done almost entirely during the night, the ends of the streets being closed, only a temporary deviation of the night traffic takes place, without any additional work for vehicles, and with much greater safety for the workmen employed in spreading the stone, in watering and sanding.

WORKING CAPABILITIES OF THE GELLERAT COMPANY'S ENGINES.

According to the indications given above as to the weights of the engines, their average speed, and the number of kilometric tonnes necessary for executing well rolled work, it is easy to determine the cubic contents of the materials that each engine, according to its weight, can roll per hour. The speed being 3 kilometres, and the number of kilometric tonnes required per cubic metre of the metalling being 4, the cubic contents that can be done by each engine is represented by $\frac{3}{4}$ of the weight of the engines expressed in tonnes. Thus :—

For the engine	of 17 tonnes..	12.75 cub. metres.	
"	" 24 " ..	18 "	"
"	" 30 ..	22.50	"

At Paris, where rolling is carried out in a very complete mode, the volume of the materials rolled per hour is less than this. It varies from 8 to 10 metres for the light engines, and rises to 15 and 16 metres for the heavier ones. According to the above data, during 10 hours' work on a layer 10 in. thick, the surfaces that can be rolled are as follows :—

Engines of 17 tonnes	12.75	square metres
" 24 "	18.00	"
" 30 "	22.50	"

THE ROLLING STOCK OF THE PENNSYLVANIA RAILROAD.

Written for "Van Nostrand's Magazine."

The following concise statement of the construction, capacity, and durability of the engines and cars of this important line of road, is contributed by Mr. G. Clinton Gardner :

LOCOMOTIVES.

There are seven classes of locomotives designated by the first letters of the alphabet, each having a large portion of their parts interchangeable one class with another—and, in fact, they are really only varieties of 3 well defined types of engines, known respectively as the 8-wheeler, 10-wheeler, and shifter.

The **A** engine, which is the leading engine over the Middle and Philadelphia divisions of the road, that is, between Altoona and Philadelphia, is an 8-wheeler with 17 by 24 in. cylinders, and $5\frac{1}{2}$ ft. drivers, and of this class there are two varieties, the one differing somewhat in plan of boiler and the other having 5 ft. instead of $5\frac{1}{2}$ ft. driving wheels.

The distribution of the weight in this engine is as follows :

On forward drivers	23,400 lbs.
" back "	22,000 "
" truck	26,500 "
Total	71,900 lbs.
Area of grate	35 × $66\frac{1}{8}$ in.
Number of flues	143
Length "	11 ft. $\frac{1}{2}$ in.
Outside diameter of flues	$2\frac{1}{4}$ in.

The **B** engine is a modification of class **A**, having cylinders 18 by 24 in., and 5 ft. drivers, with a larger boiler. These are called the "Mountain Passenger Helpers," and are used on the eastern slope of the Alleghany Mountains. One of these engines assisting a **C** engine, takes the regular passenger train, usually of 7 cars, of a total weight of 370,000 lbs., from Altoona to the top of the mountain in 24 min., a distance of nearly 12 miles, making an ascent of about 1,000 ft.

Weight of **B** engine, in working order, is distributed as follows :

On forward drivers	24,800 lbs.
" back "	22,900 "
" truck	25,400 "
Total	73,100 lbs.
Area of grate	35 × $72\frac{3}{4}$ in.
Number of flues	155
Length "	10 ft. 8 in.
Outside diameter	$2\frac{1}{4}$ "

The **C** engine is almost identical with the **B** engine, differing in the size of cylinder, plan of boiler and weight of frames, being also another modification of the **A** engine. They were designed for mixed trains to be used for local and fast freight, but have proved to be the most efficient passenger locomotives on the road, and are now in constant use for that purpose on the Pittsburgh division, that is between Altoona and Pittsburgh. An idea of the power of these engines may be formed from the fact that in ascending the western slope of the mountain on an average grade of 45 ft. to the mile, with a train of 9 cars, weighing about 487,000 lbs. it has frequently evaporated 24 hundred gallons of water in less than one hour.

The weight of the **C** class is distributed as follows:

On forward drivers	23,200 lbs.
" back "	22,600 "
" truck	25,500 "
Total weight	71,300 lbs.
Area of grate	35 × $72\frac{1}{8}$ in.
Number of flues	151
Length of "	11 ft. $\frac{3}{4}$ in.
Diameter "	$2\frac{1}{4}$ "

The **D** engine is the standard ten-wheel freight engine, having cylinders of 18 by 22 in. with $4\frac{1}{2}$ ft. drivers. These engines are used on all portions of the road except the mountain.

The total weight of the **D** engine, in working order, is as follows:

On forward drivers	18,000 lbs.
" main "	18,300 "
" back "	18,200 "
" truck	20,800 "
Total weight	75,300 lbs.
Area of grate	35 × 60 in.
Number of flues	119

The **E** engine is the standard "Mountain Freight," being a modification of the **D** engine, differing only in the drivers, and boiler. The drivers are 4 ft. instead of 4½, and the boiler is larger. These engines are chiefly in use on the mountain; upon the trial of one of them she took a train weighing (exclusive of engine and tender) 500,000 lbs. from Altoona to Gallibzen, a distance of 11 and 8-10ths miles, in 35 min., ascending a maximum grade of 96 ft. to the mile, making a total ascent of 983 ft. The regular load over this part of the road is 418,000 lbs.

The weight is distributed thus:

On forward drivers	19,200 lbs.
" main "	19,400 "
" back "	18,000 "
" truck	19,000 "
Total weight	75,600 lbs.
Area of grate	35 × 67¼ in.
Number of flues	123
Length "	12 ft 3¾ "
Outside diameter	2¼ "

The **F** engine is a 6-wheel shifter with cylinders 15 by 18 in. and 44 in. drivers. These engines are used in making up, assorting and distributing the trains at the different yards.

Its weight, in working order, is 63,500 lbs., distributed as follows:

On forward drivers	19,350 lbs.
" main "	22,450 "
" back "	21,700 "
Total weight	63,500 lbs.
Area of grate	35 × 44¼ in.
Number of flues	89
Length "	12 ft. 6 in.
Diameter	2¼ "

The **G** engine is a small class designed for construction trains and styled "Light Passenger or Ballast Engine." It has cylinders 15 by 22, with 55 in. drivers, and is mostly used for passenger and mixed service on accommodation trains or branch roads.

Its weight

On forward drivers	19,400 lbs.
" back "	19,800 "
" truck	20,800 "
Total	60,000 lbs.
Area of grate	35 × 55 in.
Number of flues	130
Length "	9 ft. 8 in.
Diameter	2 "

With all these classes of locomotives the principal castings, such as driving boxes, eccentrics, eccentric straps, etc., etc. are common, and to give an idea of their uniformity it is only necessary to state the fact that the number of patterns required for one engine is 112, while the total number required for the 7 classes is only 187; this is exclusive of the tender, which is alike for all. This, the present system of plans and classification has been followed since 1867, and the necessity for establishing some standards became apparent from the fact that five years ago the total number of 380 engines comprised 52 kinds, of which there were two or more of each and 71 odd engines; that is engines peculiar in some particular; whereas at the present time, when the engines number 496, there are but 38 kinds differing from the 7 classes (with many of these varieties of the 7 classes), and but 13 odd engines.

The trucks of these locomotives are of the variety known as the "swing centre"—the socket in which the centre pin or pivot of the engine rests has a lateral motion instead of being rigid as in the old-fashioned truck, and is suspended on links so that in passing around a curve of 350 ft. radius, which they readily do without straining either the engine or the truck, the centre line of the engine lies outside of the centre of the truck. The lateral motion also reduces the severity of a blow from guard rails, frogs, etc., upon the flange of the wheels. Chilled wheels only are used under all trucks, as it was found upon the trial of steel wheels, they would not stand the severe labor of guiding the locomotives over our crooked roads. One chilled wheel proved equal in wear to three steel wheels, and as the breakage of a truck wheel is very rare, the chilled wheels in use were thought to be the safest. The flanges of chilled wheels are soon worn smooth and highly polished, whereas those of steel wheels become rough and torn, wearing in a short time too thin and sharp for safety.

The driving wheels of the standard engines are of cast iron centres, with hollow spokes, counterbalanced with lead, and have steel tires, with the exception of those of the shifting engine, class **F**. It was found necessary to use chilled tires with these, for the same reason that chilled wheels were required for the trucks. In designing these engines, the steel tire being held in high estimation, the desire to use them whenever possible has been a controlling influence in determining the character of the engine. Having established the fact that an engine could not be guided by steel flanges, it became necessary to place the driving wheels far enough back from the cylinders to allow the entire duty of guiding the engine to be performed by the truck. Numerous efforts have been made to utilize the weight over the trucks for tractive purposes, but without success, except in connection with chilled tires, and they, being a great source of trouble, have been avoided as much as possible, not on account of breaking, but because they became loose and flat.

The locomotive boilers are made of soft crucible steel, the shell of the larger ones being 3-8ths and the other 5-16ths of an inch thick. The fire-box or furnace sheets are also of steel $\frac{1}{4}$ in. thick, with the exception of the tube or flue sheet, which has a thickness of $\frac{1}{2}$ in. and the tubes or flues are invariably of number 11 iron ; sometimes the flue sheets are made of copper, $\frac{3}{4}$ in. thick, and the majority of the boilers have a combustion chamber from 4 to 6 in. long, to avoid exposing the thick metal of the flue sheet to the direct action of the fire.

In the construction of these boilers there are no braces between the crown of the furnace and the roof of the boiler, the entire strain on the top of the fire-box being borne by the crown bars and thence transmitted by the sides to the bottom ring. This practice, in use here several years, is believed to be stronger than the old custom of connecting the crown of the fire-box with the roof of the boiler, as it is a fact that no boilers have exploded on this road in which these braces have been left out, whereas the explosions we have had were with those boilers having these braces. This practice, however, would not be safe for copper fire-boxes, as they become very weak when old. The old-fashioned method of putting in fire-box stays is used, and the stay bolts are of $\frac{7}{8}$ iron spaced $4\frac{1}{2}$ by $4\frac{1}{2}$ in., or less, screwed through the sides and headed over, the screws having 12 threads to the inch. The furnace is supplied with water-grates, being tubes of $1\frac{7}{8}$ in. outside diameter, placed $3\frac{1}{20}$ in. from centre to centre. This kind of grate has been in use for a long time, and will outlast the furnace if kept free from mud, and the grate being very open, it is rarely necessary for the fireman to touch the fire with a poker. Opposite each tube there are screw-plugs for washing out the watergrates and removing all scale or mud that may accumulate, which is done at intervals of from 1 to 4 weeks, depending upon the water-station from which the suply of water is obtained. The feed water is supplied by 1 pump and 1 injector.

The steel of which these boilers are made is tested by having a sample from each sheet heated to redness, then plunged into cold water; after which, the same piece, while cold, is bent double and hammered flat. This steel does not acquire any temper whatever by being heated to redness and dipped in cold water, but will bend double afterwards just as well as before. It is not necessary, however, to have the steel so soft, for if it works well and can be shaped without cracking, that is all that should be required. The flanging of our steel sheets is mostly done by a charcoal fire, and, after flanging, the entire sheet is heated for the purpose of straightening it and relieving the strains. This is important, as the sheets are liable to break if hammered cold without having had the strains taken out by heating. The tensile strength of the steel used is about 90,000 lbs. per sq. in. In addition to the tires and boilers, much steel is used in the other parts of the engines, such as guides, connecting rods, crank pins, axles, etc., all of which, including the tires, are of crucible steel.

With regard to the service of these engines the question has been asked, "what is the life or mileage of a steel fire-box ?" This as yet can receive no definite answer. The old fashioned steel fire-boxes, such as were built from 1861 to the spring of 1867, lasted somewhat longer than those made of copper, and upon examining the furnace of an engine which had a new fire-box of English steel in December, 1861, and was run until March, 1871, it was found in quite good condition, and far better than the shell of the boiler, which was 17 years old. There was only one small patch on the left hand edge of the crown sheet, a piece of the flange being cut off and replaced by copper. The steel in this furnace is so hard as to be difficult, if not impossible, to drill, and although doubtless hard to begin with, it is safe to say that use has not made it any softer. The flue sheet is perfectly good, but that is probably owing to its being set in a combustion chamber of about 2 ft. in length. The total mileage of this furnace was 202,852 miles, and the engine (a small freight engine of Baldwin build, cylinder 17 by 22, with $4\frac{1}{2}$ ft. drivers) being worn out, having been on the road since February, 1856, was cut up to be replaced by one of standard build.

Several steel fire-boxes built since 1861 have, however, been taken out, and one great trouble has been the cracking of the sheets around the fire door, in the flanges of the throat sheet, and sometimes the flanges of the door and crown sheets. By the change which was made in the spring of 1867, it is thought that the trouble with the door sheet has been overcome. The solid ring was abandoned, and since that time more than 100 locomotives have been built without the slightest sign of failure being perceptible about the door. With the solid ring a crack would show itself in about two years, when it became necessary to cut out a piece around the door and replace it with copper. The cracking of the flanges of the throat sheet has also doubtless been done away with by placing the flange on the water side. The intense fire striking the edge of the flange was perhaps the cause of the cracking; the metal evidently becomes highly heated, it may be to redness, and this constant overheating appears to contract the steel until it cracks, usually from the edge to the rivet hole; and if the crack passes beyond the caulking on the water side, it produces a leak that can only be stopped by a patch. The life of a steel fire-box built on our present plan will without doubt be not less than 7 years.

When steel fire-boxes first came in vogue it was the practice of some builders to still use an iron tube plate or flue sheet, and the cracking of these has sometimes been charged to steel. This, perhaps, gave rise to the question as to whether iron tube plates crack between the tube-holes the same as steel. There has not been a single flue sheet made since 1867 that has cracked between the flues, and the reason for substituting copper for steel was mainly the leakage of the flues, particularly of engines having the large and long flue, which are $2\frac{1}{2}$ in. outside diameter and 14 ft. long. This leakage was attributed to insufficient surface of the thin $\frac{3}{8}$ in. steel flue sheet, and whatever the real cause was, it is certain that tubes of the same dimension are perfectly tight in copper sheets of $\frac{3}{4}$ in. thickness. The space between the tubes is usually $\frac{5}{8}$ of an inch.

The fuel used upon this road is bituminous coal, mostly of the variety known as "Pittsburgh coal," which is excellent and makes an open dry fire, producing hardly any clinkers. It is reported as producing $8\frac{2}{10}$ lbs. of steam from water at 212 deg. to the lb. of coal, but the result on the road in practice has deen found to be about $6\frac{1}{2}$ lbs. of water to the lb. of coal. The maximum pressure carried is never over 130 lbs. to the sq. in.

All passenger engines have the atmospheric brake attachment, which consists of an upright direct-acting air pump placed on the right hand side of the locomotive, partly under the running board. It is worked by steam from the boiler and pumps air into a receiver placed under the foot-board. The pump is automatic, and as the pressure of air in the receiver is reduced by the application of the brakes its stroke is more rapid—thus the pressure is restored in a very few moments as indicated to the engineer by a gauge in the cab placed just above the steam gauge; with this appliance the stops at stations are more quickly made, thus saving much time. On the Pittsburgh Division the passenger engines take their water from water-troughs while running, which also reduces the delays, giving quicker time without increase of speed. These troughs are 18 in. wide and 4 in. deep, placed between the rails on both tracks at two convenient points, and in running over any one of the 4, they being from 1,200 to 1,500 ft. in length, sufficient water to fill the tank is taken.

CARS—PASSENGER EQUIPMENT.

The passenger cars are in no way peculiar, and may be safely considered as a fair representation of the American railroad coach. The style of finish of these cars is changed from time to time, to give a pleasing variety, but the framing and plan of seat is uniform throughout, the one having the necessary strength, while the other gives the comfort so desirable on a long run.

These together with the numerous variety of other cars, such as the open sleeper, the compartment, the double and single drawing room, the parlor and the silver palace, are capable of furnishing the travelling public with every convenience known to first class railroad travel.

The trucks of all passenger equipment are of the variety known as the "Equalizer truck" and under the ordinary day cars they have two pairs of wheels while those under the sleepers, etc., have three pairs of wheels each. The wheels are made of charcoal iron having a tensile strength averaging not much below 30,000 lbs. per sq. in., and one of these chilled cast-iron wheels weighs about 525 lbs. It is extremely rare that any are broken while in service, their mileage being not less than 100,000 miles, and in comparison with wheels having steel tires, some of which have been tried, there is but slight prospect, if any, of their ever being superseded; the flanges of the steel tires wear rapidly and soon become dangerous.

The axles used are made of soft crucible steel, and are required to stand a test, without breaking, of 5 blows under a drop weighing 1,640 lbs. from he height of 25 ft. One axle from every lot of 50 is taken at random and placed on the supports, 3 ft. apart, under the drop, and struck in the centre, then turned over, always placing the convex side up, carefully measuring the deflection each time, and if it bears the 5 blows without breaking, the lot is accepted.

As an illustration of the quality of this steel the fact may be stated, that on November 15th, 1867, one of these axles was broken with 14 blows—3 at 35 ft., one at 36 ft., two at 38 ft., 7 at 39 ft., and the last one at 40 ft.—the deflection varying from $8\frac{1}{2}$ in. to $11\frac{1}{4}$ in. These axles are of English make, rough turned all over, 4 in. at the centre and increase to $4\frac{3}{4}$ in. diameter in the wheel fit—the journal being $3\frac{1}{4}$ in. by 7 in. These journals each carry about 4,000 lbs. of dead weight, and at most not over 1,000 lbs. of load, that is under the passenger cars. Under the sleepers the dead weight is nearly the same, but the load is not over 325 lbs.

There being no record as yet of the life of these wheels and axles, they are never allowed to run under passenger equipment over 18 months after the date stamped on the axles when placed in service, and after that time they are transferred to freight equipment.

The ordinary passenger car will seat 52 persons, and a sleeper or palace car has 24 double berths, and is consequently capable of accommodating 48 persons, but each berth is very rarely occupied by more than one person. The total weight of a passenger car is 38,000 lbs.; of a sleeper, from 42,000 to 46,000 lbs.; and of a palace car, from 56,000 to 58,000 lbs. The weight of a 4-wheel truck is 6,400 lbs., and of the 6-wheel truck, 9,600 lbs. The mileage of a sleeper is about 10,000 miles per month.

The air or pneumatic brake is in use on all passenger equipment, and works well, giving the engine driver perfect control of the train, enabling him, in an emergency, to stop an ordinary train within its length, say about 500 ft. from the point at which the air is admitted to the cylinders under the cars. The air pressure necessary for all practical purposes is from 55 to 60 lbs. per sq. in., and with care a successful stop can be made with a consumption of about 13 lbs. of air pressure.

In addition to the cars mentioned, the passenger equipment consists of the half passenger or smoking and baggage, the baggage, the mail and baggage, and the express cars, and it frequently becomes necessary to use the freight-box cars for additional express freight, in which case air pipes with the hose connections are used temporarily, to convey the compressed air for air brake under these cars.

All passenger cars are lighted with ordinary coal gas, compressed to about 300 lbs. to the sq. in., and carried in fixed tanks under the body of the car. The two tanks are placed laterally on each side of the car and filled by a hose connection, at the principal stations, from a gas house—the gauge just below the governor in saloon of each car indicating the amount of gas pressure received. Sufficient gas is carried to supply one 3-ft. burner in saloon and four 6-ft. burners in body of car during 12 to 15 hours. These cars are warmed by a stove at each end of the car, burning anthracite coal, so arranged that a current of air is forced in by the motion of the train, and after being heated is distributed by air passages under the seats.

FREIGHT EQUIPMENT.

The freight cars consist of 5 kinds, designated as the "Box Car," "Stock Car," "Gondola," "Drop-bottom Gondola," and "Drop-bottom Coal Car."

The Box car is used for carrying general merchandise, grain (mostly in bulk), flour, etc. The weight of the empty car is 20,000 lbs. and will carry about 16,000 lbs. of grain and from 20 to 24,000 lbs. of flour, 216 lbs. to the barrel.

The Stock or Cattle car weighs about 19,000 lbs. and will carry about 16,000 lbs. of horses or mules, 14,000 to 18,000 lbs. of cattle, 12,000 lbs. of hogs and 9,000 lbs. of sheep. Many of these cars have an upper deck by which means they carry 18,000 lbs. of hogs or 14,000 lbs. of sheep. These cars are also used frequently for rough freight of various kinds, such as oil, pig iron, coal, staves, bark, etc.

The Gondola car and Drop-bottom Gondola are, with the exception of the trap doors, the same, and used for miscellaneous freight, but mostly for coal and timber. The trap doors are for the convenience of unloading coal on trestle work over bins, or chutes, for transshipment. The weight of the Drop-bottom Gondola is from 18,000 to 19,000 lbs., while that of the Gondola is about 2,000 less, and either will carry from 20,000 to 24,000 lbs. of freight.

The "Drop-bottom Coal car" as the name indicates, is used mostly for coal. The dropping of the trap doors of this car will discharge its entire load without shovelling. Its average weight when empty is about 16,000 lbs. and is capable of taking a load of from 20,000 to 24,000 lbs. Iron ores and other kindred substances are also carried in these cars.

In addition to these cars there is a "Maintenance of Way Dirt Dump" used in the Engineer Department, that dumps the entire load to the side of the track, and a flat stone car used for the transportation of stone in construction. This latter car is similar to the Gondola, but without sides, and having a double or stronger flooring.

The cars above mentioned comprise the equipment of the road with the exception of the Individual or Company cars that belong to parties on or adjoining the road. These are mostly built after the style of those described, with the exception of the tank cars, built for carrying petroleum in bulk. The truck used for all freight cars is the iron truck, and weighs 4,625 lbs.

ON THE STRESSES OF RIGID ARCHES AND OTHER CURVED STRUCTURES.*

By Mr. WILLIAM BELL, M. Inst. C. E.

The author, after adverting to his method of constructing a curve of equilibrium for an arch unequally loaded with continuous or discontinuous weights, or under oblique pressures, proceeded to apply it to the determination of the stresses on rigid arches and other curved structures. As the consideration of an arch of masonry was more simple than that of a rigid arch, a preliminary illustration was given by an examination of the Pont-y-tu-Prydd, an arch with small stability, with the peculiarity that its spandrels were constructed with cylindrical openings. The effect of these openings was described. To show the nature of the change of the curve of equilibrium by oblique pressure of the backing, this curve was drawn on the supposition that the backing was a perfect fluid, pressing at right angles to the back of the arch. The action of a passing load in increasing the stress upon the masonry was also examined.

The stresses of a rigid arch had hitherto been a subject of considerable difficulty, owing to the intricate nature of the mathematical analysis it was necessary to employ; and the labor of applying formulæ to trace the variation of stress from point to point was considerable. Still, before the transverse sections of arch ribs could be proportioned to the stresses coming upon them, a knowledge of this variation is indispensable. The main object of the paper was to show that the stresses at every point of an arch rib could be determined by a diagram, and that some questions, such as where the form of the rib

* A paper read before the Institution of Civil Engineers.

was neither circular nor parabolic, and when the pressure was oblique, which would be almost intractable by analysis, could be readily solved. The curve of equilibrium being the locus of the resultant of all the outward forces, the bending moment was the pressure in the direction of the curve multiplied by the perpendicular upon the tangent. The curve having been determined, the stress caused by the bending moment could be ascertained, and this, added to the uniform compression, was the total stress at any point. By shifting vertically the positions of the points of the curve at the crown and springing, the stress could be indefinitely varied, and the curve could be made to satisfy the conditions of the rigid arch of invariable span, or the rigid arch with the ends fixed. These conditions were then investigated, and gave the following results. The neutral line of the arch rib having been divided into equal parts, and the bending moments at each of these parts obtained from the curve of equilibrium, when the ends were fixed the sum of all the bending moments had to be made equal to zero; when the rib was of invariable span, the sum of the bending moments, each multiplied by the vertical ordinate of the point to which it corresponded, had to be made equal to zero; and when the ends were fixed and the rib of invariable span, the above conditions had both to be satisfied. When the section of the rib changed from point to point, each bending moment was to be divided by the moment of inertia of the cross section corresponding to it, before entering it in the summation. It was then remarked that where the curve of equilibrium touched the surface of the rib, the compressive stress was doubled, trebled, or quadrupled, according as the section was I or box-shaped, tubular, or of the form of a solid rectangle. For vertical forces only, the bending moment at any point was equal to the horizontal thrust multiplied by the length of the vertical line between the curve of the rib and the curve of equilibrium. A mathematical investigation was entered into for a circular rib, considered as a voussoir arch, or rigid arch with the ends fixed, in a similar manner to Mr. Airy's treatment of the circular rib of invariable span. It was shown that the stresses could be equally well ascertained by diagram as by mathematical investigation. When a moving load was the only force acting on an arch rib, the curve of equilibrium was two straight lines, meeting in an apex vertically above the load. As the load moved, the locus of this apex depended on the condition of the rib, as to whether it was rigid, or in the state of a voussoir arch. The action of a uniformly distributed load was then examined, and the circular rib compared with the parabolic. It was remarked that a straight or curved girder might be considered as an arch of any rise, but without horizontal thrust, and it was shown that, by drawing any curve of equilibrium for the weights, continuous or discontinuous, acting on the girder, considering it as an arch, the stress at any point was the horizontal thrust multiplied by the vertical ordinate. The action of oblique forces was then entered into, and the case of the curved gates of the Victoria Docks was examined. The stresses on the elliptical caissons used in the foundation of the Thames Embankment were next ascertained by construction. It appears that when the eccentricity of an ellipse under normal pressure was small, the curve of equilibrium was nearly a circle, whose radius was the mean between the length of the major and minor semi-axes of the ellipse; and that if a boiler, which was an arch in tension instead of in compression, were not truly cylindrical, there would be considerable transverse in addition to the tangential stress, and if the deviation from an exact circle were greatest at the riveted joints, the stress would be greatest at the weakest parts. It was then remarked, that at an ordinary lap joint, or at a part where the deviation of form amounted only to half the thickness of the plating, the stress at the surface of the iron was four times that due to the uniform pressure of the steam. This result, which showed how greatly a boiler might be weakened by an imperfection of form too slight to be detected by the eye, was not, in the author's opinion, generally known. There could be little doubt that incorrectness of form, the evidence of which was destroyed when a boiler exploded, was one of the chief causes, and hitherto an unsuspected cause, of many of the boiler explosions which occurred from time to time throughout the country. The last example chosen was the somewhat complex case of the roof of the St. Pancras Station, Midland Railway. The form of the rib differed from the circle and parabola, the section varied to some extent near the springing, and as the action of the wind on the roof was considered, the question was also one of oblique forces. The curves of equilibrium for the roof, acted on only by its own weight, were first drawn. For the actual condition of the rib, namely, that of a rigid arch with the ends fixed, the curve was contained everywhere within the depth of the rib. For a pressure of wind of 40 lbs. per sq. ft., the curve showed two maximum stresses of 4.08 tons and 4.14 tons per sq. in. The arch rib had been treated as of invariable span, but real or virtual alterations of span might be caused by changes of temperature, a yielding of the abutments, and the compressibility of the arch rib itself. It became then an important practical question to determine, for wrought-iron arches, how much the stresses might be altered by a small alteration of the span. The method of ascertaining this generally was then described, and it was found that a wrought-iron rib of 200 ft. span, 20 ft. rise, of an I or box-shaped section, and loaded uniformly, might have the stress at the crown increased from 4 tons to $6\frac{1}{4}$ tons per sq. in. This would happen if the abutments each yielded $\frac{1}{2}$ in. under the thrust, and the temperature were reduced 60 deg. below that at which the parts of the rib were put together. This result included the stress caused by the compressibility of the iron.

In order to draw the elastic curve of the rib, it was then shown how to find the displacements of the different points, by change of temperature, compressibility of the metal, and action of the bending moment. The deflection of the crown was the alteration of the rise of the rib as found by this process. Applying it to the case of the rib of the St. Pancras Station roof, the deflection of the crown was found to be 2 in., while observation had given from $\frac{3}{16}$ to $\frac{1}{4}$ in., so that the agreement of calculation with observation was very close. The author proposed to measure stresses by the direct observation of the extension or compression of a small length of the material of a structure. For a stress of 1-5th ton per sq. in., the extension of a length of 50 in. of wrought iron was $\frac{1}{1000}$ of an inch, which if magnified 50 times, would be read as $\frac{1}{20}$ of an inch by the eye. During the testing of a structure, two microscopes, magnifying 50 diameters, with scales in their eye pieces, fixed about 50 in. apart, would measure stresses of 1-5th of a ton per sq. in. in the most direct manner, and the stresses could be measured at the critical point of a structure.

The author thought that this method of observation might even be useful in another way, if, as was probable, inferior kinds of wrought iron approached to cast iron in the scale of their extensibility under moderate stresses. By taking an observation where the stress could be accurately determined by calculation, the quality of the iron which had been used in a structure might be ascertained.

THE PUBLIC WORKS OF PARIS.

From "Engineering."

At one time the Paris pavement was uniformly composed of setts measuring $9\frac{1}{16}$ in. on each side, and costing 6d. a piece; but these setts under the action of a heavy traffic became smooth and rounded, affording a bad foothold. Smaller setts were then substituted giving a more even surface; the dimensions of these are $3\frac{15}{16}$ in. by $6\frac{1}{4}$ in. and $6\frac{1}{4}$ in. deep, and they cost from £10 15s. to £13 per 1,000. This new paving varies in cost from 8s. 8d. to 13s. per yard, according to the quality of the material.

The paved surface of the Paris streets is equal to 6,077,300 sq. yards, of which 180,360 yards are taken up every year; the remaining 5,896,940 yards are maintained by 82 brigades of 5 workmen each, costing annually £21,760, or about .86 penny per yard.

The area of the metalled roads will be reduced during 1872 to about 2,000,000 sq. yards, and the expense for maintenance allotted in the budget for the coming year is £131,640. A staff of 1,105 laborers is devoted to this work, and it is found better to re-make the roads entirely than to patch them. For some years past steam road rolling has been introduced. The contractor for this work is paid at the rate of 7d. per ton per mile run by the engine during the day, and a slightly elevated rate for night work. The watering arrangements preserve the surface of the roads. Every 5 or 6 days water is poured over in abundance, succeeded by a thorough hand or machine sweeping. The mechanical brushers with one horse cost £36, and sweep 5,970 yards per hour, equal to the work of 10 men. The materials employed for the roads are :

	£.	s.	d.	
Flint, costing	0	7	0	per cubic yard.
Compact limestone . . .	0	19	2	"
Porphyry from Voutré .	1	9	3	"

The asphalt roads are composed of a compact formation of béton 4 in. thick, dressed according to the ultimate curve of the road. This formation is covered with a layer in mortar, and at the end of 4 or 5 days, when the whole has acquired the necessary degree of hardness, the application of the asphalt is proceeded with.

The raw material comes from the mines of Seyssel and of Pyrimont in the valley of the Rhone. It is a limestone impregnated with 10 or 12 per cent. of bitumen. This rock is reduced to powder and is heated in a suitable apparatus to a temperature of 150 deg. It is then loaded into carts and brought on the ground, where it is spread over the béton in layers 1½ in. or 2 in. thick, then it is well beaten down with rammers or iron rollers until it resolves itself, as it were, into the original rock. This class of road—noiseless, clean, and agreeable—presents nevertheless the serious inconvenience of easily becoming slippery and dangerous to the horses. Special care has, therefore, to be taken in washing the asphalt, and covering it with sprinkled sand, of which supplies are deposited in receptacles under the footpaths.

The maintenance of these asphalt roads includes the relaying once every 10 years, and costs at the rate of 8.3d. per square yard per annum. There are altogether 287,000 square yards ofsuch roads, and 37,000 yards laid in the metalled roads.

The foot paths and alleys are of granite or of asphalt. The granite walks cost 15s. 9d. per yard, and the cost for repair is only about .88d. per yard per annum. The asphalt sidewalks cost 3.82s. and the maintenance about 3d. per yard. The local proprietors defray in part the cost of laying down the sidewalks, and the city provides £40,000 per annum for their maintenance.

The cleaning of the public streets costs yearly £162,800, divided as follows : the purchase and maintenance of material, the staff of workmen, watering, and taking away mud and debris. Tools, such as shovels, picks, brooms, watering apparatus ; and the disinfectants, such as sulphate of iron, chloride of lime, etc., are centralized in a general depot. The annual cost is £600.

The labor of sweeping and cleaning the streets is apportioned as follows : the householders and local proprietors keep clean about one-half of the whole area, the municipal authorities, at the cost of the local proprietors, clean one-third, and one-sixth is looked after by the city government at its own cost. The average cost is about 1.67d. per square yard per annum. Connected with this service are 41 workshops of 31 workmen, and 70 workshops of 17 workmen.

The watering is done from carts or by articulated apparatus connected with a hydrant in the pavement. This second system, which is only half as costly as the first, has been generalized and operates over a surface of 1,275,700 square yards at an expense of about .005d. per yard.

The mud and general debris are lifted by contractors or the land cultivators in the environs of Paris, who employ this matter as manure. At one time the sale of the refuse brought in a considerable sum to the city, but of late years this has not been the case, and while there are a large number of collectors who pay nothing, there are others whom the municipality keep in employment. The Government of the 4th September, by a decree dated the 11th September, 1870, prohibited all collectors of manure in the streets of Paris, and compelled the inhabitants to carry direct to the carts the refuse to be taken away. This decree, which brought about a great improvement from a sanitary point of view, should also reduce considerably the cost of cleaning the streets.

It is now proposed that the municipal council should institute a commission to study this question, and at the same time that of carrying away the sewage matter and the utilization of sewage waters.

After the service of roads in the Paris administration comes that of works. This includes all the works which are executed in the public streets above the level of the roads and footpaths, the promenades and plantations, seats, columns, public announcements, kiosks, cabstands, and offices, lamps, shop fronts, the chairs and tables of cafés, etc. This service is divided into four distinct parts :

1. Promenade and plantations.
2. Lighting.
3. The concessions of the streets.
4. Public vehicles.

The growth and management of the trees in the Boulevards and avenues of Paris are matters of no small difficulty. It is necessary that they should have a good soil and a perfect drainage, that they should be preserved from damage by the public, and the deleterious effects of the gas lighting. By preference plane and chestnut trees are chosen, for they grow rapidly, give good shadow, have a beautiful appearance, and are not affected by the insects. There are to-day 102,254 trees in the Paris avenues. The cost of maintaining the trees and public seats is £7,600 per annum. As to the promenades the plan adopted was to make four grand promenades at the four cardinal points, namely, the Bois de Boulogne, the park of Buttes-Chaumont, the Bois Vincennes, and the Park de Montsouris ; afterwards to develop or to form a garden or a square in each of the 20 arrondissements of Paris.

This programme, now executed, gives to the population, besides the four great promenades, a total of 27 enclosures, covered with vegetation, and presenting a surface of at least 147 acres. The expenses for maintaining these promenades amount to £14,000, besides the cost of the plants furnished from gardens at Muette, near Passy.

The outlay incurred for the Bois de Bologne has exceeded £640,000, and £227,800 for the Bois de Vincennes. To supply the great quantity of shrubs and flowers required in the creation and maintenance of the promenades, the administration has formed vast horticultural establishments. The most important of them is the Garden of Muette, comprising an orangery, and nursery greenhouses, collectively covering an area of 73,820 sq. ft., 53,750 sq. ft. of hot beds, various buildings occupying 85,600 sq. ft., and gardens for outdoor plants. The establishment cost £16,000. There are employed on it 88 workmen, and 3,000,000 plants per annum are produced there at an average cost of .12d. each. The city possesses, besides, three establishments for raising the required trees and shrubs.

It is proposed in 1872 to reduce from £87,850 to £59,360, the outlay of the plantations and promenades. But very heavy expenses will have to be incurred, and much time must elapse before the traces of the damage done during the war and the insurrection are effaced.

STRAINS ON STRAIGHT GIRDERS AND TRUSSES.

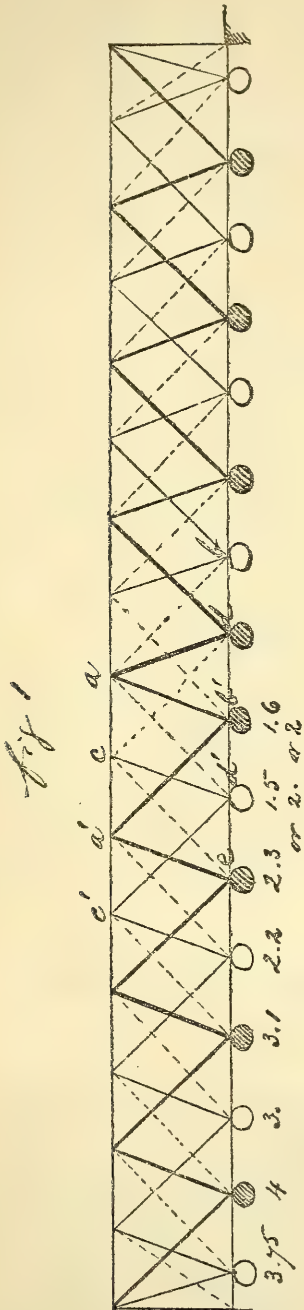
Written for Van Nostrand's Magazine.

(Continued from January Number.)

The Post truss (Fig. 1) is a compound truss of two triangular systems, the braces having a run of half a panel, and the ties, of one and a half. The weights on the ties and braces under a uniform load are determined as for the other trusses, and the horizontal strains through the chords obtained as in other cases, by multiplication of the vertical strains by the tangent of the inclined members. In the present case, the tangent of the ties = 1, and that of the braces, 0.33. The strains and horizontal increments, in loaded-panel weights are shown in the half truss, Fig. 2.

In summing the series to obtain the maximum vertical strains on the ties and braces from the rolling load, the peculiar construction of this truss at the centre, causes an interruption of the regular decreasing progression. Supposing the panel weights W′ of the rolling load concentrated at the lower apices, as in Fig. 1, we have for the coefficients of W′ in the light-lined system, (13.5 + 11.5 + 9.5 +

$6.5 + 4.5 + 2.5)\frac{W'}{16} + (15.5 + 0.5)\frac{3}{4}\frac{W'}{16} =$ $3.75\ W'$, and so on for the rest, as shown



in the figure. For the heavy-lined system, we have, $(14.5 + 12.5 + 10.5 + 8.5 + 7.5 + 5.5 + 3.5 + 1.5)\frac{W'}{16} = 4\ W'$, and so on as in the figure.

Another peculiarity of this truss is that the counter-braces connect the two systems. This renders a nice calculation extremely difficult, but it is believed that the following general considerations are correct and lead to safe results.

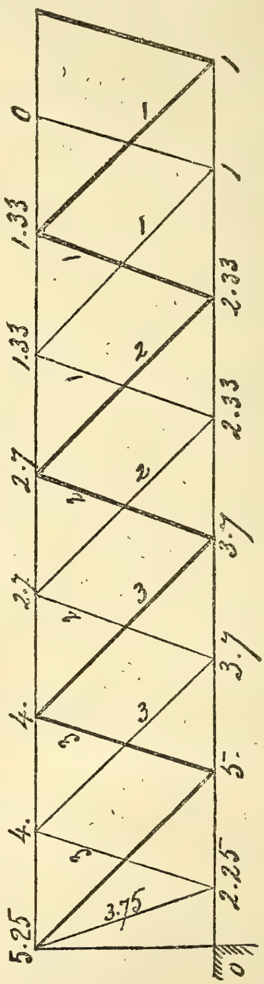


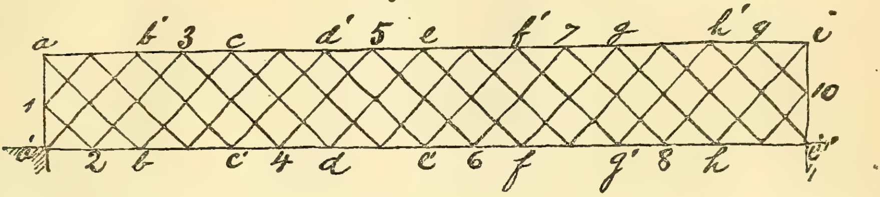
Fig. 2.

All weights and dimensions being assumed the same as for the other trusses, the counterbraces sustaining a shearing strain are *a b*, *c d*, and their symmetricals. Of these, the former sustains, vertically, 1.5 W′, and the latter, 2 W′.* When half

* Excepting for the strain on the first tie, the weight on the first and last apexes has been taken = W′ instead of ¾ W′, the difference for all other cases being but slight.

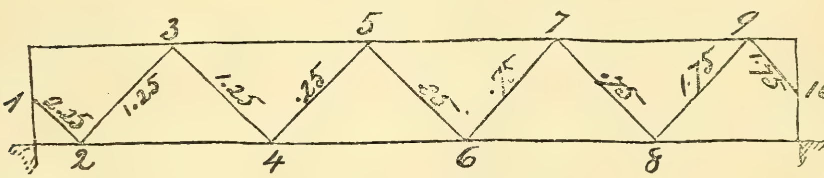
of the truss is covered by the rolling load, and the tie $a' \, b'$ is therefore under a vertical strain of $(7.5 + 5.5 + 3.5 + 1.5) \frac{W'}{16} = 1.1 \, W'$, it is conceivable that the counterbrace $a \, b$ may transmit to it in addition through $a \, b'$, the whole of that portion of the strain which the said counterbrace receives from the other, or light-lined system. This equals $0.9 \, W'$, making the whole possible vertical strain on $a' \, b' = 2 \, W'$. The two panel weights on $c \, d$

Fig. 3



are transferred to $c' \, d'$, which must therefore be strong enough to bear the additional half panel weight. If the truss be loaded from e to the right abutment, the weight of 2 panels on $c \, d'$ undergoes a diminution of $6.5 \frac{W'}{16} = 0.4 \, W'$, from the effect of the tensile strain upon it from

Fig. 4.

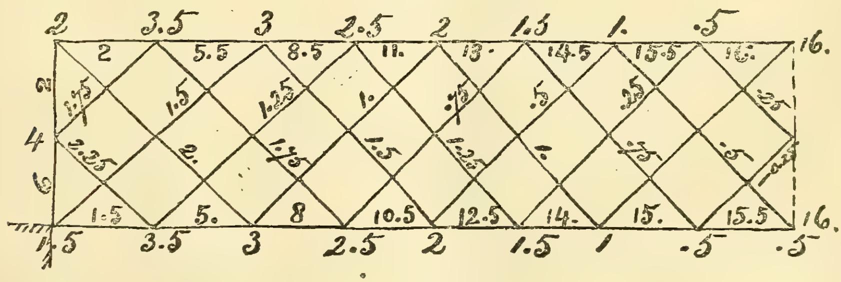


the weight at d', and therefore the strains upon the rest of the ties are sufficiently provided for by the previous calculations.

A lattice truss containing four systems of right-angled trussing requires also a rather complicated calculation.

In the truss shown in Fig. 3, let W = permanent bridge load, and W′ the rolling load, on each lower apex. In order to calculate the strains on the flanges, we must ascertain the vertical strains on the ties as braces when the truss is completely

Fig. 5.



covered with the rolling load. The weights borne by the ties and braces of the systems $a, b, c, d, e, f, g, h, i$, and a', b', c', etc., are easily obtained, for the weights on their apexes are symmetric in relation to the centre of the truss. Those at the apices of the two other systems are not symmetric, and the effect of each weight must be taken separately, and the total effect for each member deduced. Let us consider the system 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10, Fig. 4.

We have already seen that if a truss be loaded from a certain tie to the farther abutment, that the strain on that tie is diminished by placing weights upon the unloaded segment. This is because these last in transmitting a certain portion of their weights to the farther abutment, produce a compressive strain in the tie which must be deducted to find the net tensile strain upon it. This principle established, it is easy to calculate the strains on the members of the system in question.

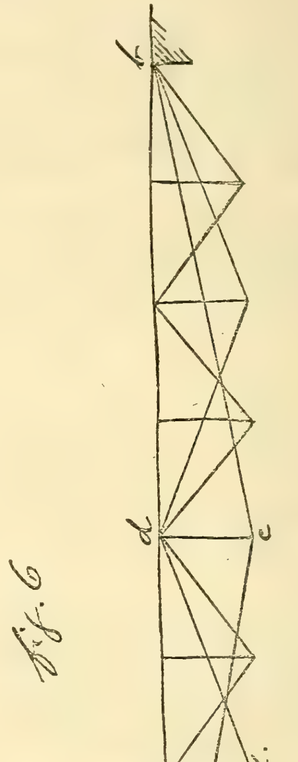
The tensile strain on 1, 2 is found by taking the combined strains of the weights on 2, 4, 6, and 8, which add up

$$\frac{36}{16}(W + W') = 2.25\,(W + W').$$

The tensile strain on 3, 4 and the compressive strain on 2, 3 from the weights 4, 6, 8, amount to $\frac{21}{16}(W + W')$. But the weight at 2 exercises a directly contrary strain on these members of $\frac{1}{16}(W+W')$ leaving a net strain of $1.25\,(W + W')$. The strains tensile and compressive on 5, 6 and 4, 5 from the weights 6 and 8, give $\frac{10}{16}(W + W)$; but from this must be deducted $\frac{6}{16}(W + W')$ from the weights 2 and 4, leaving $0.25\,(W + W')$ In like manner we get the proper coefficients of $(W + W')$ for the other members, as shown in the figure, and we have then all the elements necessary for the diagram of vertical and horizonal coefficients shown in Fig. 5.

The maximum strains on the ties and braces and the amount of counterbracing against the shearing strain, are determined as for the other trusses.

This example is the same as that given by Mr. Stoney in his treatise on strains, Vol. I., p. 105, except that we have considered the rolling load as passing over the bottom chord. It will be seen that the results arrived at differ materially from those given by Mr. Stoney in his diagram. This is owing to his incorrect allotment of the permanent strains on the two unsymmetrically loaded systems. That Mr. Stoney's results are incorrect is readily seen by comparing the diagram for uniform strains with the table on page 106. By the diagram, the strain on diagonal 3 when the bridge is uniformly loaded, equals 2 panel weights, while by the table, the maximum strain on this member is given correctly, as 1.75 panel weights. It is evident that this diagonal, in Mr. Stoney's example, is under the same strain whether the truss is entirely covered or only from the further abutment to apex 3, for the weights 1 and 2



do not bear upon the system of which diagonal 3 forms a part, at all, and therefore their presence or absence cannot affect it.

The Fink truss, shown in Fig. 6, differs from all those we have already considered, being in fact a series of independent trussed beams. It is best suited for undergrade bridges. Maximum strains of all kinds occur when the whole bridge is covered with the rolling load. When so loaded, the horizontal strain throughout $a\,b = \frac{W\,L}{8\,D}$, W representing total load, both fixed and rolling, and the strain on the ties $a\,c$, $c\,b$, is to this as the length of $a\,c$ is to that of $a\,d$. Compression on $d\,c = \frac{W}{2}$. Strain on $a\,f$, $f\,d = \frac{W\,L}{16\,D} \times \frac{a\,f}{a\,e}$. Compression on $e\,f\,\frac{W}{4}$. Strains on the other sub-trusses are calculated in a similar manner.

SUBMARINE BOATS.

From "The Engineer."

Just now the torpedo is attracting considerable notice as a new engine of war. To us, islanders, it may, perhaps, almost prove the weapon of the future, at least, if the supremacy of the sea, our present boast, be ever threatened. It is mainly as an instrument of defence that we at present regard torpedoes, but they may also be used—as indeed, they have been—for offensive purposes. To this end, a submarine boat, a boat that can be submerged and work below the water as well as above it, is required. The project is at present almost chimerical, yet, perhaps, it may be not altogether without interest to trace the history of the invention.

Many more attempts have been made to attain it than is generally supposed. Of course, the idea of a boat to work below water is a very old one. Roger Bacon, who lived in the 13th century, mentions submarine vessels amongst the other marvels he enumerates. "Moreover," he says, "instruments may be made wherewith men may walk in the bottom of the sea or river without bodily danger, which Alexander the Great used, to the end that he might behold the secrets of the seas, as the Ettrick philosopher reputeth, and these have been made, not merely in times past, but even in our days." Again, in another place, our author speaks more definitely on the subject: "We have seen and used in London a warlike machine, driven by internal machinery, either on land or water. Succeeding years have shown us a vessel which, being almost wholly submerged, would run through the water against waves and wind, with a speed greater than that attained by '*Celonibus Londinensibus expeditissimis*' (the fastest London pinnaces—Facciolati)."

These accounts, however, are rather mythical, and the first true submarine vessel we know to have existed was one which Cornelius Van Drebbel tried upon the Thames, by command of James I. This was moved by 12 rowers, and according to Leibnitz, went for some distance under the water. Whether it received external air for respiration the same author does not know, but from other sources we learn that the vitiated air was purified, or said to be purified, by an artificial liquid invented by Pierre Van Drebbel, the son-in-law of Cornelius. This liquid was sprinkled about, and the air thus again became suitable for respiration. Bishop Wilkins, in his "Mathematical Magic," speaks favorably of the invention. In 1692 Papin wrote to Leibnitz on the subject of a machine, which seems to have been a simple form of steam engine for moving ships. The correspondence which ensued is preserved in the Great Seal Patent Office, but has never been published; in it Papin speaks of a submarine boat invented by himself. It was to be moved by oars at the side, and could be caused to rise or sink by pumping air into or out of internal vases. It had a mercurial gauge, was steered by a rudder, and lighted by glass windows; air for respiration could be pumped in through a tube, by "a Hessian pump," that is to say, a rotary flyer with vanes; the vitiated air escaped by another tube, while a third enabled the diver to attack an enemy's ship.

Probably these and similar inventions, though applicable to warlike purposes, were chiefly intended to fulfil the same end as the diving bell, the principle of which was known (it is first mentioned by John Taisnier, who was born at Hainault, in 1509), though, of course, it was not yet brought to perfection by aid of the numerous mechanical appliances now in use. About the same time, or a few years earlier than the date of Papin's machine, J. A. Borelli invented a sort of diving apparatus. This, indeed, was not a boat, but more nearly resembled the diving dresses of the present day; still it deserves notice as a curiosity. It consisted of a large metal vessel filled with air, which could enclose a man's head and be secured round his neck. About the wearer's waist was a cylinder holding air, furnished with a piston to enable the diver to raise or lower himself. To the feet of the diver webbed pins with hooks at their ends were to be fastened, so that he could swim or crawl crab-like along the ground. No mention is made of any weight to be attached to the diver's body, but certainly he must have required a good deal to carry down so much air with him. More nearly connected with our subject is a *navis urinatoria*, described by the same inventor—a covered vessel with bags open to the exterior water, by pressing which the water would be squeezed out and the boat lightened, so that it might ascend. This was certainly the most primitive form of force pump imaginable, and one by no means unlikely to work a good deal better in theory than in practice. However, Borelli is not the only inventor whose discoveries are open to the same objection. To move this boat, oars were to protrude through airtight holes, or there might be "one flexible and elastic oar with a broad blade placed on the vessel's stern, by the vibration of which a ship could be propelled forward, as fishes are by their tails." (Borelli, "*De Motu Animalium*," Rome, 1691.) In his "*Acta Eruditorum*," published in 1683, J. Bernouilli took the trouble to prove that Borelli's machine was impracticable, as indeed it apparently was. Ten years later, in 1693, an engine of apparently similar nature was patented by John Stapleton, but hardly any description of it is preserved. The heading of the patent tells us that it was a "new and extraordinary engine of copper, iron, or other metall, with glasses for light, and joynts soe contrived as to permit a person enclosed in it to walke and move freely with it under water, and yet so closely covered over with leather as sufficiently to defend him from all the jumps thereof." There was also an engine that would "swim upon the water in the most violent storms," and sink to the bottom and rise again when required. Besides these two machines—the former of which was apparently a sort of diving-dress, while the latter seems to have been a true submarine boat—the patent included a method of "defecating" or purifying air after breathing. This was to be used if the supply of fresh air was cut off by any means. One year before this (1692), John Williams invented an engine "for the conveyance of four men 15 fathom and more under water in the sea, whereby they may work 12 hours and more without any danger, which said engine will be of great use and advantage for the taking up of wrecks and shippes that have been and shall be lost in the sea." No description of the machine is given, but—a thing very uncommon in the case of old patents—there is a drawing of it still preserved in the Rolls Chapel. By this it appears to have been merely a long water-tight cylinder, closed at the bottom, down which men could pass. At its lower end, which of course rested on the bottom, were windows and holes fitted with water-tight sleeves, through which men could pass their arms so as to take hold of exterior objects. Doubtless this engine should not be classed among submarine boats, since it was only a bad substitute for a diving-bell, resembling a machine described by Vegetius, in 1532. This latter consisted merely of a cup which fitted the diver's head, and had a long leather pipe attached to it, the end of which reached to the surface of the water.

A boat is also mentioned as having been made during this century by one Day, which could move below the surface; but the inventor was drowned in his second experiment, so that little or nothing is known of his machine. The next submarine vessel we hear of was of French origin. In 1722 some experiments were made by Dionis of Bordeaux, an account of which is given in the "Journal Encyclopedique" of August 1, 1772. From this we learn that his machine carried 10 persons a distance of 5 leagues below water in the Bay of Biscay, and that it remained below 4½ hours, without having its supply of air renewed.

Such were, in brief, the earliest attempts at submarine navigation of which we have any record remaining. They are, of course, more interesting in an antiquarian point of view than in any other, especially as so little description of any of them has been preserved, that we can scarcely do more than make out the principles upon which they were constructed, and can certainly derive no useful information from any one of them. Certainly the easiest way of treating such accounts is to put them all aside as forming a set of idle tales; but this is not a very philosophical style of treatment, and probably there is more truth in them than we are altogether ready to believe. At all events, there is nothing in the results said to be achieved by any of the machines, which is absolutely impossible, as later experience has amply shown.

So much, then, for the earlier inventions, that form what we may call the legendary or mythical age of the science. Those we now come to are much more fully recorded, and belong, in fact, to our own mechanical age. The invention of torpedoes gave a great impulse to the endeavors to make a vessel which should carry them; hence the next person we come to is remarkable for having been at once the inventor of these infernal machines and the first contriver of a submarine vessel that we possess a full and accurate description of. David Bushnell, of Connecticut, seems undoubtedly to have been the originator of the notion of blowing up a ship by an explosive engine applied to her hull. The stationary torpedo he does not appear to have employed, but only to have conceived the plan—not even yet fully perfected—of attaching a torpedo to an enemy's ship. Hence his submarine boat. Of this we have ample description. A MS. account of it is preserved in the Patent-office Library in London, and there is besides a paper originally read by Captain Bushnell himself, before the American Philosophical Society, and republished in the "Repertory of Arts," vol. xv., p. 385, which gives a full account of it. From these descriptions we gather that the boat was tortoise-shaped, very strongly built of two elliptical plates of iron bolted together at the edges, and affording in the hollow between them sufficient space for a single person. At the bottom it was heavily loaded with lead to insure stability, but it could also take in ballast for the same purpose. Besides the operator, air sufficient to support him for 30 min. could be contained in the inside. At the top was an opening with an air-tight door for entrance, at the bottom another door or valve through which water could be admitted when it was desired to descend, while a couple of force pumps served to eject the water when ascent was wished for. There were also two ventilating tubes on the top of the boat, which closed of themselves under water, and opened in the air. For motion there were two screw-shaped oars —one vertical, the other horizontal. They could be turned either by the hands or the feet, and are remarkable as being an early instance of the use of the screw-propeller. Part of the ballast was fixed so that it could be suddenly let down about 40 ft. or 50 ft. by a rope, and by this means the boat be permitted to rise suddenly in case of accident. There was no light, except such as might be admitted through the "dead-eyes" above, so the compass and the water-gauge, by which the depth of immersion could be ascertained, were rubbed with phosphorus to render them visible. Such was the boat in its principal parts as relating to its powers for navigation; but scarcely less important, considering the end it had to serve, was the arrangement for attaching and exploding a torpedo. In the fore part of the boat was a tube through which passed a screw that could be driven into the wooden bottom of a vessel and left there. Attached to the screw by a line was a powder magazine, which was cast off at the same time as the screw was detached. The screw being driven in, the infernal machine floated up against the side of a vessel, and was then exploded at a certain time by a clock-work apparatus that was started by the casting off the machine. This was the whole contrivance, and a most ingenious one it was. It was completed in 1775, with the object of being used in the War of Independence. The first experiments were upon hogsheads loaded with stones, and these being successful, the inventor was encouraged to make an attempt upon the Eagle, a 64-gun ship belonging to the English. The boat was sent out under the direction of a man named Ezra Lee, who succeeded in getting under the vessel ; but when attempting to fix the screw into its hull he struck a bar of iron. Trying to find another place, he lost the ship and was obliged to rise to the surface to look about him. Daylight was then coming on, so he deemed it advisable to return, *re infecta.* On his voyage home he found the torpedo impeded the boat in the heavy sea, so he cast it off, thus setting the clockwork in motion, and at the appointed time it blew up. A detailed account of the adventure, taken down from Ezra Lee's own lips, is given in "Silliman's Journal" for April, 1820.

Another attempt upon the Cerberus frigate, in 1777, was hardly more successful. Bushnell tried to tow a torpedo against her side by means of a long line. This line was discovered by the crew of a schooner lying astern of the frigate and hauled in. While they were examining the torpedo, not knowing what it was, it blew up, and destroyed the schooner, killing three of the four men on board. Two or three months later in the same year Bushnell filled a number of kegs with gunpowder, and, after fitting them with percussion fuses, tried to float them down the Delaware agains the English shipping. Unfortunately for the success of the enterprise, the kegs were frozen up for some time, and at last drifted down in the daytime. The crew of a barge attempted to take one up, when it exploded and killed four of them. Upon this a terrible commotion was aroused, no one knowing the cause of the explosion. The soldiers turned out, the populace rushed upon the quays, and everywhere was the greatest confusion, until at last the origin of the sudden attack was discovered. Upon this the fleet opened fire upon the kegs, and continued until every floating object had disappeared. Naturally enough, this vigorous warfare upon an inanimate foe gave great amusement to the Americans, and the "Battle of the Kegs" was celebrated in not a few mock-heroics, amongst others in a poem by the father of the writer of "Hail, Columbia."

At last Bushnell, disheartened at the ill-fortune of his endeavors, gave them up and left America. Afterwards returning, he changed his name, and lived for some time in retirement in Georgia. At his death his real name became known, and his possessions were inherited by his proper heirs, a descendant of whom is now resident in New York.

Of the value of his invention we have direct testimony in a letter from Washington to Jefferson, written September 26th, 1785. In this General Washington speaks of Bushnell as a man of great mechanical genius, though he did not believe in the practicability of his schemes. There was no doubt, the letter said, that Bushnell had a machine capable of conveying him to any depth, by aid of which he could fasten an infernal machine to the hull of a ship. The objection which General Washington saw was, that there were too many difficulties to be overcome, and that the chances of success were too small. "I thought," he says, "and still think, that it was an effort of genius, but that there were too many things to be combined to expect much from the issue, against an enemy who are always upon guard." This was true, and still remains so; for, though the opinion was passed upon one of the earliest inventions of its kind, no means have yet been discovered of accomplishing the same object with certainty and security. Bushnell, however, did this much: he showed that the offensive use of torpedoes by means of a diving-boat was possible, and he left it for future engineers to perfect the system he had originated.

It is naturally only during war that we hear of new weapons being contrived. Hence we have to pass over twenty years before coming to another boat of the sort we are discussing. Fulton, when engaged upon his steamboat, went to France (1796), and when there tried to revive a project of his for a machine which could move under water. By its aid, "he hoped to deliver France and the whole world from British tyranny and oppression" (Colden's "Memoir of Fulton," p. 15). His first experiment was made on the Seine. He attempted to impart motion to kegs of gunpowder under the water, and then explode them; but this scheme, like all others for contriving an automatic torpedo, failed, the Minister of Marine pronouncing it impracticable, as did also the Batavian Directory, to whom Fulton afterwards applied. At last Bonaparte, always ready to favor any scheme which gave him a chance of overcoming the English upon their own element, gave him money, with which he continued his experiments at Havre and Brest (1801). He then so far perfected his Nautilus—such was the name he gave his boat—that he could immerse it 25 ft. under water, and remain there an hour. During this time the crew were in darkness, or at least they had only such light as a window in the bows of the boat could admit, since candles or other lighting apparatus would consume too much air. The boat could sail on the surface, but not well; and thus belonged to the class of diving boats, or *plongeurs*—boats intended only for occasional and temporary immersion. It took about 2 min. to prepare her for immersion. On one occasion he plunged to some depth, moved about 500 yards, came to the surface, again plunged, and returned to the spot from which he had started. On another occasion he remained below water for 4 hours and 20 min. without inconvenience, having taken down a globe of about a foot cubic capacity, filled with compressed air. He succeeded in demolishing an old brig in Brest harbor, and attempted to blow up an English man-of-war; but when he was on the point of attaching his torpedo the ship moved away, and he was unable to find her again.

Fulton does not seem to have carried his experiments beyond this to France; but in 1805 he was in England, where, in order that his identity might not be known, he adopted the name of Francis. Of his experiments here he has left us an account in a curious and rather scarce work called "Torpedo War," published in New York in 1810. He tells us how he got permission to make attempts upon the Dorothea, a strong-built Dutch brig, which was moored for the purpose off Walmer Castle. In this case he did not use his submarine boat, but towed 2 torpedoes against the ship by means of a line 70 ft. long stretched between 2 boats. After a day or two's practice with blind torpedoes, he succeeded in towing 2 that were filled with powder against the vessel's sides, where they exploded and blew the ship to pieces. "In 20 sec.," says Fulton triumphantly, "nothing was seen of her but floating fragments." It was rather curious that among the spectators was an officer who declared, 20 min. before the explosion, that if a torpedo were placed under his cabin when he was at dinner he should feel little concern for the consequences. Of his unsuccessful attempt against the French fleet, made shortly before his experiment on the Dorothea, Fulton makes no mention in his book. In this case the machine exploded prematurely, and the gunboat attacked was not injured. His next experiment was in America, in New York harbor (1807). Here the locks by which the torpedoes were to have been exploded turned downwards, so that the powder fell out of them and they missed fire. On a second attempt the torpedo exploded at the wrong time, but on a third trial the ship was blown up. From the evident uncertainty of the machines they naturally came to be regarded with no great favor; still we must remember that the means at Fulton's command were very imperfect; his row-boats and torpedoes, exploded by flint-locks, might hardly have been expected to accomplish more. Owing to the ill-success of his designs, Fulton seems to have given up his scheme of a submarine vessel, as indeed he soon after did all his attempts at making torpedoes, and devoted himself to his steamboat. During the war with America torpedo-boats of different sorts seem to have been used, but with no great success. "Nile's Register" (American) speaks of one which escaped pursuit by diving like a porpoise.

As with many other inventions, the advocates of the new schemes were very sanguine as to their powers, and hoped, by means of the new engines, to destroy or render useless all the fleets of the world, and thus render the seas peaceful. Fulton, writing to one William Brent, said: "If successful, their benefits to America will be immense, for I still assert, and every reflection confirms my opinion, that these submarine mines must go to the annihilation of military navies, and consequently produce the liberty of the seas, relieve us of all the trouble and expense of our foreign negotiations, and turn the whole genius and resources of our people to useful arts." An expression of Lord St. Vincent shows the same feeling. After hearing from Fulton a full account of his machines, he declared that "Pitt was the greatest fool that ever existed to encourage a mode of warfare which they who commanded the seas did not want, and which, if successful, would deprive them of it." Whether we still have command of the seas remains to be seen; at least we may hope that the question will not have to be solved just yet awhile. At all events, we are hardly strong enough to make it worth our while to despise the use of torpedoes—weapons adapted, beyond all others, to coast defence. As to the inhumanity of the machines—a question upon which the minds of their earliest opponents were greatly exercised—of course the progress of civilization during the past 2 years has quite settled that question. Indeed, all warlike inventions from gunpowder unwards have, each in their turn, been condemned after the same fashion.

From the time of Fulton to the breaking out of the American Civil War no submarine vessels seem to have been constructed. Several patents, indeed, were taken out in England for inventions of this sort, but none of them seem to have been much experimented with, or to have had much success. In 1805 John Schmidt and Robert Dickinson invented a sort of diving machine, which was to be moved by oars working at its lower edge. In it the vitiated air was to be free from carbonic acid by providing for its absorption by caustic alkali. This is noticeable as being apparently the first time this means was used for the purpose. As yet nobody seems to have succeeded in really purifying air by caustic alkali, but there seems no reason why it should not ultimately be done. The difficulty is to separate the impure air from the remainder, and expose it specially to the purifying action. The next English patent connected with the subject was granted in 1854 to J. H. Johnstone, for a vessel, invented by Messrs. Payerne and Lamiral, with several compartments, some open to the water, as in a diving-bell. Propulsion was to be effected by a steam engine, whose fuel was "a chemical composition." The air was to be purified by an alkaline solution, while oxygen or condensed air might be carried, to be used as need required. The following year Casimir Deschamps and Charles Vilcocq patented a "free diving boat," to be propelled by a screw turned by the hand. Its chief peculiarity consisted in an arrangement for an electric light at the top. A "Nautilus," described in the "Journal of the Society of Arts," March 6th, 1857, as the invention of Major Lears, was not really a boat, but a sort of diving-bell, which was not suspended from above, but ascended and descended by the admission and emission of air from above through tubes. It could be moved by men walking on the bottom, and pressing against the inside, but no other means for horizontal motion were provided. A machine of the same sort was at work in Cherbourg harbor in 1855, while as far back as 1776 the Society of Arts had given a prize to Mr. Spalding, of Edinburgh, for a similar invention. In 1859 another submarine boat was invented by J. M. Masson ; in it the chief features of novelty are described as consisting in the compression of the air before descent, and its increased compression by means of the generation of carbonic acid gas within inflatable india-rubber bags.

The outbreak of the American war gave great impulse to the use of torpedoes, in fact it was in the defence of the Southern coast that these weapons were first used to any real extent in war. Hence various attempts on both sides to construct a submarine boat which should be used to carry a torpedo. For this purpose two sorts of boats were used, one submarine, the other not. In spite of the difficulty of getting a small vessel close to a ship without being observed, swift steam launches on more than one occasion managed to explode a torpedo against the sides of a hostile ship, sometimes with considerable effect. The Federal ship Memphis was severely injured by one of these "Davids"—as they were called from their diminutive size—and the Ironsides damaged, but not so severely. When Charleston was taken, 9 boats, specially constructed for this purpose, were found there. They were "cigar-shaped," very low in the water, and by no means particularly safe, one of them having, it is believed, been swamped by the wave raised by the explosion of its own torpedo. They trusted to their small size to escape detection, while the same fact made them a difficult target for their opponent's guns. On the other side, the Confederate iron-clad Albemarle was sunk by Lieutenant Cushing with a steam-launch carrying a torpedo on the end of a spar. The ship was moored to a wharf with a barrier of logs round her ; but Lieutenant Cushing, with the most reckless daring, actually charged the barrier, partially burst it in, and succeeded in exploding the torpedo under the quarter of the iron-clad, which immediately went to pieces.

These were the most important instances during the war of the attack and injury of ships by torpedo rams which had not the power of being submerged. One instance, and one alone, there is of a ship having been destroyed by a submarine boat. The Housatonic, a Federal sloop of war, was lying outside Charlestown harbor on the night of February 17th, 1864, when the officer of the deck noticed something like a plank floating close to the ship; it came rapidly towards him, and reached the ship's side about two minutes after it was first observed ; in another minute the explosion occurred, before the engines could be backed, or any preparation made to repel the tiny foe, especially as from the position of the guns it was impossible to fire at it while close under the ship's side. Immediately on the explosion the ship sank stern first, the crew, with five exceptions, saving themselves by going into the rigging. The destruction therefore of the ship was complete, but it was bought at the expense of the loss of the attacking boat, which was never again heard of. It was supposed either that she went into the hole made by the torpedo in the Housatonic, or that she was swamped by the sinking of the ship. Recent explorations by divers have shown the latter to be the case. She seems to have been a remarkably dangerous craft, for three times before, she had sunk and drowned all, or nearly all her crew, but had been on each occasion raised, till at last, her mission accomplished, she sank out at sea, to rise no more.

She was built of boiler iron, 35 ft. long, and was manned by a crew of nine men, eight of whom worked the propeller by hand, while the ninth steered. She could be submerged to any depth; in smooth water her speed was 4 knots. It was intended that she should dive under the keel of an anchored vessel, and drag a floating torpedo against her, which should explode on touching the ship's side. On this occasion, however, she seems to have adopted the plan of carrying the torpedo at her bows, as was usual with torpedo-boats. It is also noticeable that she did not approach the Housatonic below water, but was visible from the deck while nearing her. A few months later, a similar attempt was made on the U. S. steamer Memphis, but the boat was perceived fifty yards away, so the ship slipped her cable and went ahead. Owing to this movement the boat passed under the stern of the steamer, and it is supposed that the screw broke the spar on which the torpedo was fixed, for she disappeared. In appearance she was described as being like a ship's boat turned bottom upwards; she was about 25 ft. long, and painted lead color.

At an early period of the war the Government of the United States paid a Frenchman $10,000 for an invention of a submarine boat, and arranged with him to superintend the working of it. It was intended especially to blow up the Merrimac. Unfortunately, as soon as the boat was completed the Frenchman decamped, and as no one understood it she was never much tried. She was cigar-shaped, and was intended to be sunk by admitting water into a compartment and raised by its expulsion. She was to be be propelled by 16 oars, the blades of which were like a duck's foot, and collapsed during the forward stroke. To purify the air there was a vessel containing lime, and a bellows attachment for forcing the air through it. It was said that the Frenchman's plan was to emerge from the boat in a diving dress, attach a torpedo, and leave it to explode by machinery. A more perfect torpedo boat, but not a submarine one, is the Spuyten Duyvil, constructed at the end of the war, for the United States Navy. A description of this most remarkable vessel will be found in a book published in New York, by Lieut.-Commander J. S. Barnes, United States Navy, under the title of "Submarine Warfare," a work to which we also owe the account of the boat above referred to, and much information on the subject of torpedoes as used during the American wars.

In England we have not, of late years, had any notable inventions of this sort, the principle being one patented by Mr. Merrian, an American. Even in this there are not many principles of novelty. The boat is of ovoid shape, and consists of several compartments, in one of which the crew can work, while the others are to be used as reservoirs of air, to be stored up at any required pressure. The bottom is a heavy cast-iron plate; in it are several doors, one of which is inclosed within an air-tight compartment, so that it can be opened to the water, if needed, as in a diving-bell, without affecting the pressure of the air in the other compartments. Fore and aft are heavy weights, which can be raised or lowered, to act as "suspended ballast," or even as anchors. A screw propeller is arranged on a swinging frame, so that it serves as a rudder. Forward is a bar with suitable gearing for attaching a torpedo without going out of the boat. The boat is intended to be used both for military and other purposes.

A few years before, a foreign patentee, named Rivie, took out a patent for a boat, consisting of two concentric cylinders, between which water was to be admitted. Also W. Bauer, of Munich, in 1853, invented a submarine boat, which was to be driven by a gas engine. Air was to be supplied from above by pipes. In the sides were holes fitted with water-tight sleeves (as in Williams' invention, 1692), through which the arms of the crew could be thrust, so that they might work outside. The same inventor in 1866 patented a submarine vessel capable of a certain amount of independent motion, by aid of a screw propeller, but intended to be let down by chains from a ship.

In the Paris Exhibition of 1867 a model for a submarine boat was exhibited. It was not allowed to take any sketch, and the following description is taken from an account of it given in "A Treatise on Coast Defence," by Von Scheliha (London, 1868). The model is a French one. The dimensions of the boat are:—Length, 43.3 metres; height, 3.36 metres; width, 7.5 metres. On the top is a deck. She is to be propelled by a screw, placed in the usual position. The engine is worked by compressed air, as is also a pump for emptying or filling water reservoirs at the bottom of the boat. There is an apparatus by which it was said the boat could be instantly lowered or raised to the surface. On the top of the vessel a life-boat was secured by screws. Besides the main screw, a small vertical screw above the boat is intended to assist its ascent or descent. A tube for a torpedo, to be fired by electricity, is attached. Whether any experiments have been made with this boat does not appear, and the late war has not given many opportunities for testing its use, or, possibly, we should have heard more of it.

Such, in brief, seem to have been the principal recorded instances we have of vessels of this nature. From them it will appear that the problem of submarine navigation is, at least, not insoluble, whatever may be the difficulties in the way. True, these difficulties are so great that the general opinion of engineers is in favor of torpedo-rams, which have no power of being submerged, as—with all the danger attending them—being less risky than the diving boats. Still there seems no reason why they should not eventually take their place among engines of war. Before this can be the case, the immense danger attendant on their use must be got over by their being made more perfect and sure in their working than they as yet are. As for the supply of air, the boat need only be submerged for a short time, and sufficient air for a small crew can easily be taken down in a compressed state, even without the assistance of any purifying or disinfecting agent. The use of "suspended ballast," which might be cast off instantly, if required, so that the boat would rise to the surface, would get rid of the danger arising from the slight difference between the weight of the boat and that of the bulk of water displaced, so that a very small derangement is enough to make her sink at once. True, the motive force is a difficulty. Steam is, of course, out of the question, from the great amount of air consumed, and hand power is hardly sufficient, while it involves the presence of a comparatively numerous crew. Perhaps the gas engine may supply the want, as the material for the supply of the engines is capable of being so immensely compressed that it takes up hardly any room to speak of. How the remaining chief difficulty, that of directing the boat under water to the required spot, is to be got over, it is not easy to say. This is the great problem, and though as far as we can trust the accounts of their exploits, Fulton and Bushnell accomplished it, modern engineers have not been so successful. Perhaps the most that can be hoped for is, that a boat should by night approach within a certain distance of an anchored vessel, accurately lay its course, and then dive below her, and fix a torpedo to be afterwards exploded. Percussion torpedoes must of necessity be somewhat dangerous to the boat which carries them, as well as to the ship attacked. Altogether the difficulties do not seen insuperable, and perhaps the next maritime war will see a flotilla of these tiny but venomous war ships. How effective they would be if they could be made safe and certain in their action, is obvious. Two or three of these insidious little vessels might destroy a whole fleet of iron-clads, whose weak point, like that of Achilles, is in the heel. True, it is said that the way iron-clads are built, in several compartments, would prevent one of them being sunk by a torpedo; but this is very doubtful, and it is much more probable that a torpedo well fixed to the hull of the finest iron-clad in the world would soon decide its fate. Besides, even the mere fact of the presence of torpedo boats has a very harassing effect upon a fleet, any one of which may suddenly, without a moment's notice, or a chance of self-defence, be blown into the air. Such considerations render it certain that the Goliaths of the sea will, in case of war, have to encounter the attacks of "Davids," such as the best of those used in the American war, or boats like the Spuyten Duyvil above referred to; whether their place will be taken by a true submarine vessel cannot as yet be said. It is at least less unlikely than is generally supposed.

GRADIENTER SURVEYING.

By H. HAUPT, C. E.

Written for Van Nostrand's Magazine.

An experimental survey has just been completed for the extension of the Shenandoah Valley Railroad, from Covington, Va., to Russelville, Tennessee, the results of which, as regards economy and rate of progress, are so extraordinary, that a brief account of the system which has been adopted may not prove uninteresting.

The number of miles surveyed was 300; the whole time in the field about 5 months; the whole cost of the survey, $1,850, of which $1,050 was for salary of the assistant in charge, leaving only $800 to cover expenses of wagon and party, including supplies and outfit.

A considerable portion of the route was through brush and laurel thickets, where roads were cut for the ox wagon which carried supplies.

The average daily progress was 3 miles, maximum 7½ miles; but on long summer days 10 miles in open ground would be practicable.

The instrument used was Würdemann's gradienter, to which stadia wires for reading distances by means of rods had been added.

DESCRIPTION OF GRADIENTER.

The gradienter consists of a light but very powerful telescope, with attached spirit level and compass box, horizontal limb graduated from zero to 360 deg., circular spirit level attached to limb, and instead of vertical limb, a peculiar arrangement for measuring angles of elevation called a *percentage screw*.

This is the ordinary form of the gradienter as manufactured for the Coast Survey Department, but to adapt it to railroad experimental surveys, three stadia wires were added, the middle horizontal wire intersecting the vertical wire in the axis of the telescope, the other two forming spaces having the relative proportion of 1, 2, and 3.

The percentage screw is the great feature of this instrument. It is finely and accurately cut, and carries a horizontal disc of about 1½ in. in diameter, on the periphery of which are 100 subdivisions. This disc revolves in contact with a vertical graduated scale, and the parts are so calculated and adjusted, that one complete revolution of the percentage screw corresponds with one division of the scale, and each division marks 1 ft. in 100 of elevation or depression. The percentage screw subdivided this foot into 100 parts with surprising accuracy, showing great nicety of mechanical construction.

In testing the instrument at a distance of 500 ft., the elevations as determined by the percentage screw would seldom vary more than an inch from true levels; and although this would not be sufficiently accurate for canal surveys or railroad final locations, yet for experimental lines such an instrument is of great utility, and it can be used as an ordinary level with less rapid progress where great accuracy is required.

RODS.

The rods used were of peculiar form, constructed by the writer to facilitate the reading by the assistant of levels and distances at the same time. Each rod consisted of two pieces 3 in. wide, ½ in. thick, and 10 ft. long, connected by hinges so as to shut together like the leaves of a book, and thus protect the graduation from abrasion. One side of these rods was graduated in feet, tenths and hundredths from the bottom up, and read as an ordinary levelling rod by the assistant. The other side was graduated from the top down for distances, by first measuring accurately 500 ft., and marking the space covered by the extreme wires. This space being subdivided into 5 parts, each part would represent a distance of 100 ft., and each of these spaces was again subdivided into 100 parts representing feet. The graduation was peculiar and very legible.

MODE OF USING THE GRADIENTER AND RODS.

The adjustments of the instrument are simple, but as the threads of some of the most important screws are fine and delicate, care must be taken not to strain them.

The instrument being adjusted, the first operation consists in levelling by the sensitive circular level attached to the horizontal plate. Next, to bring the zero of the percentage screw in contact with the zero of the scale, when the level attached to the telescope should also be horizontal. If it is not, the instrument is out of adjustment. Next, place the zeros of the vernier and limb in juxtaposition and clamp them. Next, turn the object end of the telescope towards the north and unscrew the needle; when the needle has settled, bring the zero of the compass arc to it by means of the tangent screw, and clamp firmly. The telescope is now in the direction of the meridian, and the verniers at zero ; the needle may now be screwed up ; it is not used for reading courses, but only to determine the meridian, for which purpose it is made long and sensitive. The vernier is now unclamped and the courses read from 0 deg. to 360 deg.

The observer now turns the telescope to the back rod, and, bringing the top hair to the top of the rod by means of the percentage screw, reads and records the distance and the course.

Next bring the zero of the percentage screw to the zero of the scale. If the rod can be seen, the level can be read at once; if not, the telescope must be elevated or depressed, so as to bring the middle wire against the rod. It is most convenient in practice to turn the percentage screw a given number of complete revolutions, as it renders calculation more simple. A single example will be sufficient for explanation.

Suppose the distance as recorded is 480 ft., that the level from the observer strikes below the bottom of the rod, and that the telescope has been elevated 5 turns of the percentage screw to bring the rod into view, as each turn corresponds to 1 ft. in 100, 5 turns would be 5 ft., and in a distance of 480 ft., the elevation of the line of sight would be $480 \times 5 = 24$ ft. above the level. If this line should strike the rod at a reading of 5.42, then $24 - 5.42 = 18.58$, which would represent the level of the instrument *below* the bottom of the rod, and the reading would be entered in the column of back sights 18.58.

Suppose the ground continued to descend, and the forward sight should read 30.20, the difference of level between the two stations, equal to the difference between the back and forward sights, would be $30.20 - (-18.58) = 48.78$ ft. It will be perceived that by this system *negative* rods can be read, which is not possible by the ordinary system of levelling, where, if the line of sight strikes below the rod, the instrument must be moved to a higher level. It is also possible, by means of the percentage screw, to read *positive* rods of 40 or 50 ft. with considerable accuracy, and thus avoid the short intermediate stations required in ordinary levelling.

The survey of the Shenandoah Valley extension, just completed by O. Barrett, Jr., is the first upon which this system of surveying has been used. The results, however, are very satisfactory. The cost per mile as compared with former surveys, has not been more than one-fourth, and the daily progress double. The engineer records at each setting of the instrument courses, distances, total distance, back sight, forward sight, total level, and slopes. It is not absolutely necessary that a man in his party should be able to read or write, but it is convenient to have an axe man who can mark stations. One axe man and two rod men constitute the party. Each of the rod men should carry a short bill hook suspended from his belt to be used in cutting through thickets.

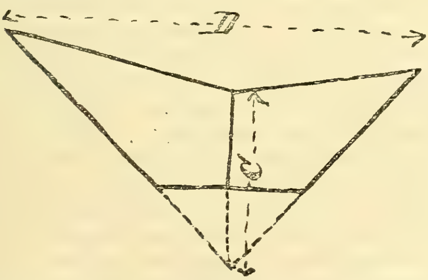
One rod could be dispensed with, but the progress in open ground is much more rapid with two.

Instead of using stakes exclusively, it is preferable, where practicable, to mark stations on trees, fences, rocks, and buildings, and to mark with paint. The measurement of distances by the stadia wires is, on broken ground, quite as accurate as ordinary chaining. And in crossing streams, marshes, or other obstructions, it has great advantages; they scarcely retard progress where measurement by chain would be impracticable.

A SIMPLE FORMULA FOR EARTHWORK.

Written for Van Nostrand's Magazine.

The computation of earthwork is generally affected by the use of tables, but the engineer not unfrequently finds himself unprovided with these, and is then obliged to go through with a great deal of tedious figuring in taking out his quantities. It is hoped that the following simple formula may be occasionally found useful in such cases.



If the side slopes were continued under the road-bed, they would meet at a certain point, which, with a given width of formation and ratio of slope, would be at a constant distance below grade, and form a continuation of the centre height, as shown in the figure. There would be also, a certain constant solid under-formation in excess of the actual quantity to be taken out, in a given section. This solid can be easily calculated, once for all, for any given road-bed and slope, and reserved as a subtractive quantity to be deducted from that obtained by computing the whole solid above and below the road-bed.

Let C = the centre height at one end of a section of 100 ft., *plus* the constant distance of the point of junction of the two side slopes under the road-bed, and D = the sum of the distances out, at the same end. C′ and D′ = the same at the other end, and P = the constant subtractive solid already mentioned.

The total end areas above and below grade are easily obtained from these data. Thus, the area at one end $= \frac{C\,D}{2}$, and at the other, $\frac{C'\,D'}{2}$. The mid area $= \frac{C''\,D''}{2}$.

The prismoidal formula gives for the cubic yards in a 100 ft. section :—

$$S = \frac{\frac{100}{6}\left(\frac{C\,D}{2} + \frac{C'\,D'}{2} + 4\,\frac{C''\,D''}{2}\right)}{27}$$

C″ and D″ are obtained by taking the arithmetical mean of C, C′ and D, D′. We have therefore,

$$S = \frac{100}{162}\left(\frac{C\,D}{2} + \frac{C'\,D'}{2} + 4\left\{\frac{\frac{(C+C')}{2}\,\frac{(D+D')}{2}}{2}\right\}\right)$$

Reducing, and subtracting P, we obtain the working formula—

$$S = 0.3086\,(2\,C\,D + 2\,C'\,D' + C\,D' + C'\,D) - P$$

In ordinary calculations the first factor may be taken at 0.31. When the excavation runs out, C′ = the constant height under the grade, and D′ = the width of road-bed, the first factor $= \frac{L}{324}$, and the subtractive solid $= \frac{P\,L}{100}$.

The above calculations are of course applicable to embankments also.

Mr. John Warner has based some excellent earthwork tables upon the continuation of the side slopes below grade, with the subtraction of the "Redundant

Prism," but it is believed that the above adaptation of the prismoidal formula has never before appeared in print.

In this connection, it may be in place to give the following convenient formula for side heights:

Let C = centre height of cut or fill.
R = reading of rod at station.
R′ = " " side stake,

Then in cut, whether up or down slope,

$$\text{Side height} = R + C - R'.$$

And in fill, whether up or down slope,

$$\text{Side height} = R' + C - R.$$

FOUR-WHEELED LOCOMOTIVES.

From "Engineering."

During the past 2 or 3 years there has sprung up on many of the Continental railways, and particularly on some German lines, a strong predilection for 4-wheeled tank and tender locomotives; and so extensively are such engines now being employed for almost all classes of traffic on the railways to which we refer, that it appears to us desirable that we should consider here their advantages and disadvantages. First, then, it is claimed for the 4-wheeled engines, by those who advocate their employment, that they are less costly than the 6-wheeled type; that the whole weight is available for adhesion; that they pass readily round curves; and that there is a less variation of the load on the different wheels when the engines are running than occurs with 6-wheeled locomotives. That the advantages thus claimed are important, it is impossible to deny, and the only question is, therefore, whether they can really be obtained by building locomotives with 4 wheels only. With the exception of the first advantage mentioned, namely, that of less cost, it is, however, we consider, extremely doubtful whether the claims can be substantiated, while even as regards saving of cost, we doubt whether there is really so much in it as the advocates of the 4-wheeled engines appear to imagine. It is undoubtedly true that with a given amount of boiler power, and a given size of cylinder, an engine will cost less if carried on 4 wheels than if mounted on 6; but the difference is, in our opinion, not sufficiently great to counterbalance the extra risk involved in running the 4-wheeled engines. If an engine be mounted on 4 wheels only, the springs must be heavier, the bearings and axle-boxes larger, and the axles stronger than would be required for the coupled wheels of a 6-wheeled locomotive of the same total weight; while the frame, being less efficiently supported, will also require additional strength to give it the same power of resistance which it would possess in a 6-wheeled engine. These various matters combined will go no inconsiderable way towards counterbalancing the cost of a third axle and pair of wheels, and the fittings connected with them.

The claim that in the 4-wheeled engines all the weight is available for adhesion must be allowed, of course; but whether this is in all cases an advantage or not is another matter. The truth is, that the amount of adhesion required to turn to account the whole power which a locomotive is capable of developing varies, inversely, according to the speed at which the engine is run; the higher the speed, the less being the adhesion required. Thus, let us suppose the case of a locomotive having a boiler of such size as to be capable of supplying steam sufficient to develop in the cylinder 10,000,000 foot-pounds of work per minute over and above that required to overcome the frictional or other resistances of the engine itself. If, now, the engine is moving at a speed of but 1,000 ft. per minute, or a little under 12 miles per hour, a pull of 10,000 lbs. will have to be exerted to use up the power developed, and the adhesion weight will have to be such as will enable this pull to be exerted without causing the engine to slip. If, however, the speed of the engine be increased to 5,000 ft. per minute, then the pull necessary to use up the 10,000,000 foot-pounds of available work developed per minute in the cylinders would be $\frac{10,000,000}{5,000} = 2,000$ lbs. only, and the adhesion weight required would be only $\frac{1}{5}$ of that necessary in the case first supposed. Thus, although in the case of engines travelling at slow speeds it is desirable to have a great proportion of the weight available for adhesion, yet in the case of fast-running engines this is by no means always necessary, particularly if the trains worked by such engines do not require to be started very quickly. While, therefore, the 4-wheeled arrangement possesses an advantage when adopted for shunting engines or goods engines travelling at low speeds, the fact of it enabling all the weight available for adhesion ceases to be an advantage when the speed becomes higher. Thus, on the Rhenish Railway—where some 4-wheeled tank engines are in use, working the traffic for the steam ferry at Duisburg, and where, also, 4-wheeled goods engines are employed for hauling the coal and mineral trains on the Osterath-Wattenscheid line—it has been found that, although these locomotives are capable of exerting great tractive power when moving slowly, yet that it is impossible to keep up sufficient steam to maintain this tractive effort at a higher speed. For this reason the 4-wheeled engines are not used on the main line of the Rhenish Railway, as, the load on each axle already averaging 15 tons, the boiler power cannot be increased.

As regards the power of traversing curves easily, there is much to be said against as well as in favor of 4-wheeled locomotives. At low speeds such engines do, from their short wheel base, undoubtedly get round curves well, but at anything like a high speed this short wheel base, combined with the overhanging weight, occasions a great wear of the wheel flanges when curves are being traversed In the majority of cases, also, the drawbars are arranged so that the pull exerted on the train acts at a considerable leverage in opposition to the guiding force exerted by the wheel flanges, and thus increases the wear of the latter. To a great extent, however, this wear due to the pull exerted on the train is a preventable evil, and we shall not, therefore, urge it as an inherent objection to the 4-wheeled system. Quite apart from this, however, the shortness of the wheel base of the 4-wheeled engines exaggerates the effect on the permanent way of all lateral oscillations, whether on curves or straight lines, and this increase of effect, of course, shows itself on the wheel flanges. Thus on the Saxon State Railway, where a number of 4-wheeled locomotives are in use, it has been found that in these engines the wear of the leading tyres is greater than in the case of 6-wheeled engines with a 2 ft. longer wheel base. On the Dresden and Chemnitz branch of this railway there are in use some 4-wheeled engines, weighing, in working order, 27½ tons, some of these engines having 4 ft. 6 in., and some 5 ft. wheels, while the wheel base is 8 ft. 6 in. The tyres of the 4 ft. 6 in. wheel engines are found to run on an average 20,350 miles, and those of the 5 ft. wheel engines 14,200 miles before re-turning becomes necessary, while the tyres of some 6-wheeled engines, weighing 37 tons, and having 4 ft. 6 in. wheels, with a wheel base of 10 ft. 4 in., run 19,900 miles without the tyres being turned. It should be mentioned, however, that in these latter engines the trailing and leading wheels were transposed after 14,200 miles had been run. The authorities of the Saxon State Railway, in the report made by them the year before last to the German Association of Railway Engineers, affirmed that the 4-wheeled engines were very unsteady on the curves, and that even on straight and level lines they were not considered fit to run at speeds of over 6 German miles (= 28¼ English miles) per hour. Similar reports were also obtained from some other lines, but it is only fair to state that precisely opposite evidence was afforded by several railways, the authorities of the Wurtemburg State Railway in particular affirming that the 4-wheeled engines employed by them run easily over curves, show no lateral oscillation at high speeds, and are, in fact, equal in this respect to the best 6-wheeled engines.

The assertion that in 4-wheeled engines there is a much less variation of the load on the axles than in the 6-wheeled type, is one for which we believe there is no foundation whatever. In fact, both theoretical considerations and practical experience are directly opposed to it. All who have ridden on the old 4-wheeled locomotives of the Bury type, formerly largely used in this country, will well remember how those engines used to "gallop" at high speeds, while at the present day it is only necessary to ride on the foot-plate of an ordinary contractor's 4-wheeled tank engine and watch the action of thesprings, to be convinced that the latter are in 4-wheeled engines by no means free from variation of load. Notwithstanding these facts, however, great equality of load on the springs has been extensively claimed as a special attribute of 4-wheeled engines, and even Baron von Weber, whose admirable researches on the stability of permanent way are familiar to our readers, has gone so far as to condemn 6-wheeled engines in favor of 4-wheeled, almost exclusively on account of this supposed good quality. In December, 1870, we published an account of the Baron's ingeniously conducted experiments in 6-wheeled locomotives, and gave a Table containing a summary of the results he obtained. These results showed that in the case of leading wheels carrying a normal load of $5\frac{3}{4}$ tons per wheel this load was sometimes increased when running to over 9 tons, and sometimes diminished to but $1\frac{1}{2}$ tons; while in the case of another engine, of which the wheels had a normal load of 3.65 tons, the load rose in some cases to 7.35 tons, and actually fell in others to as little as 5 cwt. only—an amount less than $\frac{1}{14}$ the normal load. These and other similar results obtained from the 6-wheeled engines on which the experiments were made appear to have led Baron Von Weber to condemn such engines altogether, for he advocates strongly the exclusive use of 4-wheeled engines. Besides, however, the rough-and-ready experience to which we have alluded, exact experiments are available to prove that the asserted maintenance of equal loads on the wheels of 4-weeled engines is a purely imaginary quality. Such experiments were carried out some time ago on the Saxon State Railway, with some 4-wheeled engines, having a normal load of 7 tons per wheel, when it was found that while running, this load fell to as little as 4 tons, and increased to as much as $11\frac{1}{4}$ tons. The engine on which the experiments were made had an independent spring above each axle-box; but there are also on the same line some other 4-wheeled engines in which the weight is carried on 3 points only, the 2 trailing springs being connected by a transverse lever. These engines are said to run steadier than the former, but less freely. The variation of load recorded during the experiments with the 4-wheeled engines on the Saxon State Railway is undoubtedly less than that registered during Baron von Weber's trial of 6-wheeled engines; but it is also undoubtedly in excess of the variation which occurs in 6-wheeled engines properly mounted on their springs, so that the weight is carried on 3 points only.

We do not hesitate to say that an engine with 4 coupled wheels of which the springs are connected on each side by compensating beams, while either the leading or trailing end of the engine is supported centrally on a properly constructed bogie, possesses a degree of freedom from variation of the load on the wheels which cannot be obtained in any ordinary 4-wheeled type of engine.

We have hitherto said nothing respecting the disastrous results attendant upon the fracture of an axle of a 4-wheeled engine, and it is really unnecessary that we should enlarge upon the point. Altogether we consider that the balance of evidence is decidedly opposed to the conclusion that a 4-wheeled type of locomotive can be satisfactorily employed for any but slow traffic, or for shunting purposes. For such uses 4-wheeled engines may undoubtedly be very frequently employed with advantage, and had their use been confined to such services, we should have had little or nothing to say respecting them here. As it is, however, we cannot but regard their increasing employment on the Continent for working fast passenger traffic with a certain amount of apprehension, and we fear that the practice of so employing them may eventuate in a sad lesson, the results of which, although they may be deplored, will be irremediable.

REPORTS OF ENGINEERS' SOCIETIES.

ANNOUNCEMENTS TO MEMBERS AND ASSOCIATES.—I. Is is believed that several names of members and associates elected at the Bethlehem meeting in August, 1871, have been accidentally omitted by reason of a loss of the portion of the records of that meeting. Such persons or their friends are requested to communicate with the secretary.

II. All members and associates who have not paid their dues, are requested to do so at once, by sending in postal orders, or check or money, $10 to the secretary.

All members and associates who pay their dues for each current year, strictly in advance, will have sent to their address regularly and weekly, the "Engineering and Mining Journal," which is the organ of the Institute, and will contain the proceedings and transactions, and all important papers read before the Institute, and all notices of meetings. Back numbers cannot, as a general rule, be sent.

III. It is expected that the more important papers read before the Institute, and the debates thereon, will be published in annual or semi-annual volumes, to which those members and associates will be entitled who have paid their dues.

IV. Authors of papers are requested to notify the secretary in advance of the meetings, giving the subject and length of their papers. Attention is also called in this connection to rules 12 and 13.

V. The next meeting of the Institute will be held in Philadelphia, beginning on Tuesday, February 20, 1872, at 8 P. M. The Council will meet at 3.30 P. M. of the same day. Messrs. Lesley, Drown, Blandy, Fraser, Gaujot, and Lyman are the local committee of arrangements. The sessions will be held at the University of Pennsylvania, in Ninth street, above Chestnut, and the headquarters of members will be at the Bingham House, corner of Eleventh and Market streets.

Martin Coryell, Secretary, Wilkesbarre, Pa.

THE DERBYSHIRE INSTITUTE OF MINING, CIVIL, AND MECHANICAL ENGINEERS.—The second meeting in connection with the above Institute was held at Chesterfield, under the presidency of Lord Edward Cavendish. It was stated that not fewer than 21 new members had just been admitted. Papers were read by Mr. E. Bromley, "On Hydraulic Engines;" by Mr. R. Howe, "On the Guibal Fan Experiments;" and "On Machinery for Washing and Separating Coal and Mineral Ores," by Mr. Howard. An animated discussion followed the reading of each paper, but as the subjects contained in the two last papers had not been properly ventilated the discussion was adjourned. The desirability of erecting a memorial hall to the late George Stephenson was introduced to the meeting by Mr. C. Binns, of Clay Cross, one of the vice-presidents of the Institute, who showed the great necessity of erecting such a building in a town near to which Stephenson once resided, and in which he was interred. He, however, intimated that, as an effort was being made for obtaining funds to enlarge the accommodation at the hospital, the Council had thought it better to let the matter rest for 12 months, until the hospital scheme was completed.

THE AMERICAN SOCIETY OF CIVIL ENGINEERS.—At the meeting held on the afternoon of January 17th last, Mr. Theodore Allen read a paper describing an apparatus operated with hydraulic power, used along shore, by the New York Department of Docks, to take soundings for permanent foundations, down to solid earth, or bed rock; whereby a pointed hollow steel shaft, connected by a cross-head with two hydraulic cylinders, was forced downward from a floating scow, through mud and soft earth, until a resistance was met superior to the water pressure within the cylinders.

A discussion followed upon the manner of sounding for foundations, and of sinking salt and oil wells.

Mr. Collingwood called attention to the operation of the pneumatic siphons used to remove material from the west caisson, New York bridge; and the difficulty experienced, from the rapid cutting away of the elbows in the pipes by the upward currents of sand.

A large and valuable donation to the library of the Society by Mr. Arthur was announced.

At the meeting held in the evening of February 6th last, Mr. Collingwood presented an investigation of the amount of air required for healthful respiration, within the west caisson of the New York bridge; the number of laborers employed therein, and of gas lights burned, being taken into account.

Mr. Macdonald read a paper upon the "Strains in a triangular roof truss, and the use of counter braces in lattice bridges," showing the errors made by recent writers upon these topics.

Samples of tool steel from the American Chrome Steel Works were exhibited.

IRON AND STEEL NOTES.

DEPHOSPHORIZING IRON ORES.—Metallurgists have for a long time past made great efforts to discover some practical method of dephosphorizing iron ores which would enable them to utilize many varieties of ore which, owing to the presence of phosphorus, yield only an inferior quality of iron. The quantity of ore so contaminated is enormous in many of the more recent geological formations, such as the oolitic, cretaceous, and tertiary formations, where the ore is either found in the shape of a carbonate or a hydrate of iron, always intimately contaminated by phosphate of lime. Of this character are the heavy beds of iron ore in the Middlesbrough district, in Luxembourg, Lothringen, Bavaria, Hanover, Bohemia, and many other localities. It was the phosphorus which forbade the use of a number of these ores for many years, until modern metallurgists had learnt, by using larger furnaces and more limestone, and by adopting a judicious admixture of other ores, to extract a cheap and tolerable iron from them. Nevertheless, it has always been a desideratum to neutralize the injurious influence of the phosphorus in one way or the other. Some engineers have endeavored to extract the phosphorus from the ore, wherein it is contained in the shape of basic phosphate of lime, which is insoluble in water, and the object of all their exertions being to render this compound soluble by converting it into acid phosphate of lime by the action of other mineral acids, which would combine with a part of the lime, and set an equivalent of the phosphoric acid free to combine with the rest of the phosphate of lime, thus forming a super-phosphate. This idea is stated to have been lately successfully carried out by T. Jacobi, of Adalberthutte, at Kladno, near Prague, by exposing the ore to a solution of sulphurous acid in water, or to the simultaneous action of sulphurous vapors and cold water, when this acid forms a soluble compound with the lime, and at the same time converts the rest of the phosphate to the soluble form, so that it can be washed away with cold water. The inventor exhibited his process during the last meeting of the Association of German Engineers and Architects, at Prague, on November 3d, 1871. The samples of fibrous and fine grain bar iron and puddled steel made from such dephosphorized ore, and produced to the Association, were of an excellent character, and found unanimous approval. The sulphurous gas is either produced by burning sulphur or by the calcination of pyrites or other minerals containing sulphur. The same end has been attained by another engineer, B. Osann, of Potsdam, by employing in a similar way diluted hydrochloric acid, which is obtained very cheaply in quite a novel mode. At the above-mentioned rock salt mines of Stassfurt and Leopoldshall, large masses of chloride of magnesium are obtained, together with the salts of potassium, and are thrown away as valueless. Now, if this chloride of magnesium, which contains always a considerable amount of water, be heated to about 110 deg. Cent., or 230 Fahr., it gives up so much water as to form a trihydrated salt of chloride of magnesium, and if this is rapidly heated to the melting point of lead it is decomposed, giving up vapors of hydrochloric acid, when hydrate of magnesia is left as residue in the retort. The hydrochloric vapor acts exactly as was described of the sulphurous acid. Both of the processes above described are worthy of attention; but the information we have received concerning them is not as yet sufficiently detailed to enable us to form any decided opinion regarding their practical merits. Other metallurgists have sought to get rid of the phosphorus during the puddling of the iron, or even just before, when the pig iron runs from the taphole in the moulds. For removing the phosphorus during the operation of puddling, Director Spamer, at Ilsederhutte, in Hanover, adds to each heat of 500 lbs. of pig iron about 6 lbs. of fluoride of calcium (fluorspar), which readily melts when brought in contact with the iron, so that it can be intimately mixed with it, when the fluorine combines with the silicon of the iron to fluor silicon, and phosphoric acid is absorbed by the lime and carried into the tap cinder; or finely powdered fluorspar is thrown into the iron moulds before they are filled with liquid iron when tapping the blast furnace. In both instances the result obtained is said to be excellent, the cold-shortness of the bar iron having entirely disappeared. This appears to be a modification of the Henderson process, which has lately attracted much attention in this country.—*Iron Age.*

STEELED WHEELS.—This novel title is given to railway wheels made by a process which must rank among the great improvements recently made in the working of metals. We refer to the improvements in car wheels, patented in 1868 by Mr. W. G. Hamilton, engineer, of the Ramapo Wheel and Foundry Co., which, after 4 years of experimental trials, is now brought prominently before the public.

Mr. Hamilton, who is well known to the railway profession, through his "Manual of Useful Information for Railway Men," has worked out the problem of making chilled car-wheels out of non-chilling irons, and at the same time increasing the strength of the mixture above that of the most expensive charcoal irons.

The process consists in part in melting scrap steel, with the ordinary charge of pig metal, in the cupola, by which an increase of strength of from 20 to 50 per cent. is given to the metal.

Messrs. A. Whitney & Sons, the extensive wheel founders of Philadelphia, who have been testing the practical utility and value of the process, have made some 15,000 wheels, during a continuous working during the last 3 months, and report it a most complete success.

That this process will enable them, by adding to their usual chilling charcoal irons a portion of non-chilling soft charcoal irons, or anthracite metal, to produce a car wheel of greater strength, and at a much less cost, than with high-priced chilling charcoal irons alone.

To the railway community the value of this improvement will be understood, when it is known that the supply of charcoal irons is yearly diminishing and the cost increasing, and that the steeled metal gives greater security to their rolling stock. A company has been organized to grant licenses to manufacture, under the name of The Hamilton Steeled Wheel Co. of Philadelphia, of which J. Edgar Thomson, of the Pennsylvania R. R., is the president; Mr. Hamilton vice-president, with a board of direction, amongst whom are—Thos. A. Scott, M. McCullough, Henry L. Pierson, A. J. Cassutt, and other prominent railway men.

RAILWAY NOTES.

THE CANAL CAVOUR.—A Milan paper gives the following as the revenue derived from the Canal Cavour during the last five years:

	Francs.
1866	438,000
1867	494,000
1868	729,500
1869	733,000
1870	885,000

This does not include the revenue derived by the Company from the State canals purchased from the Government. It may safely be anticipated that, after the completion of the important branch canals now in construction, the revenue of the company will increase considerably, and render it a most profitable undertaking.—*Journal of the Society of Arts.*

MACNAIR'S INVERT PERMANENT WAY.—A trial of this way has recently been made upon the North London Railway. It has had a trial of 18 months on the North British Railway, and a sample has been in wear on the North London line for 3 months. The North London line is laid with double-headed steel rails of 80 lbs. weight to the yard, their depth being 5½ in. The locomotives traversing the line weigh 45 tons, with 14 tons weight upon each pair of driving-wheels. A part of Mr. Macnair's invert way carries flat-bottomed steel rails of 70 lbs. to the yard, and 4½ in. deep; these are expected to stand the traffic as long as the Company's heavier ones. Another part consists of iron rails of similar pattern 66 lbs. to the yard and 4½ in. deep. The principle of the "invert" is, as the name indicates, a supporting of the rails upon a series of inverted arches, formed by wrought-iron plates, about 3 ft. long, 12 in. wide, and ¼ in. thick. These are put in loose, and their extremities abut against small butt plates, riveted to the under side of the rail. The rails forming the roadway are connected together by tie-bars, made of common angle iron, placed at suitable intervals, and fastened by the same rivets. In this manner a roadway of very uniform elasticity is produced. The peculiar motion of the substructure calls into exercise the transverse strength of the rail itself, which, as borne upon the points of the inverts, acts always like a beam in carrying the load rolling over it, the points of support themselves yielding to the weight as it comes over them, so that even the supporting points take their due places in the common elasticity of the whole. The form of the inverts has suggested to many the idea of springs—a purpose they are in no wise intended or fitted to fulfil; their proper object is correctly expressed in their name, and their action under a train is thus: When the weight comes on the anterior end of the first invert, that end is depressed; the invert then slides slightly forward along the curve of the ballast, on which it rests until the posterior end is elevated in front of the weight, and is thus kept up to its duty of supporting the rail as the load approaches. As the weight travels on, the posterior end of that invert, as well as the anterior end of the next invert, are then depressed, the posterior end of the second invert rising up similarly to the support of the rail in front of the load, and as the posterior end of the first invert descends, its former sliding action is reversed until its anterior end is brought up again under the rail behind the load, so that at this stage the rail which forms the beam is supported between the anterior end of the first invert and the posterior end of the second invert, whilst the load itself is over the intermediate ends of them both. When the load is intermediate between the two ends of an invert, they both contribute to the support of the shorter length of rail which then carries the load; and so on along the whole length of the railway, the points of support for the rails, whilst acting as beams, being alternately the two ends of the same invert on the opposite ends of two contiguous inverts. The general conditions of the system, as shown, appear to indicate that there will be a saving in the cost of maintenance, and more durability of the materials, than in any sleeper roadway. In respect to cost, in a general way, it seems to be proved that the invert road will not cost more than an ordinary sleeper road in this country; but abroad, where the expense of transport becomes an important item, the advantage of the invert over the sleeper will be considerable; the weight of the invert road being 190 tons per mile, as against 230 tons per mile for the sleeper road, both carrying the like weight of rails.—*Journal of the Society of Arts.*

RAILWAYS IN ASIA MINOR.—The Turkish Minister of Public Works publishes the following official note on the subject of this enterprise: "The railway in course of construction between Scutari and Ismidt, is one of the numerous public benefits which do honor to the spirit of initiative of His Imperial Majesty the Sultan. His Majesty, gratified with the progress made with this line, and acting upon the regenerating ideas with which he is ever animated, has further ordered the Minister of Public Works, through the Grand Vizier, to establish a network of railways throughout the whole of Asia Minor, by means of branches, communicating with the Scutari and Ismidt line. In conformity with the Sultan's order, engineers have been sent to Ismidt to examine Mount Seugud, and to make all necessary surveys, with a view to the extension of the line to Eski-Sheir, as a first instalment of His Majesty's splendid scheme. As the works on the Scutari to Ismidt line are comparatively far advanced, considering the time employed upon them, there is reason to believe that this section will be completed by next September, that the extension to Eski-Sheir will be in readiness during the following spring, and that both lines can then be joined. The important subject of the branch line is now under earnest consideration at the Ministry of Public Works.—*Journal of the Society of Arts.*

PHILADELPHIA AND READING RAILROAD.—The production of rails at the Company's rolling-mill during the year amounted to 19,113 tons, at a cost of $64.69 per ton, including in the cost the old rails re-rolled, at an estimated value of $45.03 per ton.

The following table shows the product of the mill for each year since its erection, with the number of tons of each year's production since removed from the track:

	YEARS.				TOTAL.
	1868. Tons.	1869. Tons.	1870. Tons.	1871. Tons.	Tons.
Product	8,971	17,037	17,557	19,113	62,678
Worn out, 1868 ...	5				5
" 1869...	175	2¼			177¼
" 1870 ..	904	164½	1½		1,070
" 1871 .	1,418	614	240	3½	2,275½
Total worn out	2 502	780¼	241½	3½	3,527¼
Per cent........	.278	.046	.014	.00018	.056

From this statement it will be seen that of the 62,678 tons of rails rolled by the Company and laid in the track during the last 4 years, but $5\frac{6}{10}$ per cent. have yet been worn out. Of the production of 1868, $27\frac{8}{10}$ per cent. have been removed up to this time, showing that $72\frac{2}{10}$ per cent. of the first year's manufacture are still in use, although a tonnage of over 20,000,000 has been moved over them at speeds varying from 10 to 40 miles an hour.

KANSAS and her railways have received the personal attention of Mr. Samuel Bowles recently. He says, in the "Springfield Republican":

"Kansas is sure of a large population and great wealth. Railroads are rapidly opening up all her rich fields to population and improvement. No State of all the new West can hope to surpass her in the power of her materialism, and no State among them all is so pledged as she by the prayers and patriotism that labored over her birth, to direct and govern this power with a high moral sense, and inspire her wealth with spirituality. If she fails to prove something like the Massachusetts of the West she will certainly be false to her birthright and stand as a discouragement to holy effort.

ENGINEERING STRUCTURES.

The Superstructure of the St. Louis Bridge.—A full sketch of the novel and extraordinary difficulties encountered in manufacturing and testing the materials for the superstructure, and of the original, ingenious, and very costly means by which they are now at length completely overcome, would form one of the most instructive and fascinating chapters in the history of practical engineering. They relate, mainly, to the preparation of the steel work, of which the quantity and proportions of its parts are not more unprecedented than was the securing of a quality capable of bearing the very exacting tests. The Keystone Bridge Co., of Pittsburgh, contractors for the entire superstructure, sub-let the contract for the steel to the Wm. Butcher Steel Works, of Philadelphia, who, at the outset, made additions to their buildings, furnaces, rolling mills, straightening machines, etc., which seemed to give assurance of success and dispatch. The first large forgings required were the steel anchor bolts, from 22 to 36 ft. long, and $5\frac{3}{4}$ in. diameter. Each bolt is required to sustain, tested at the shop, a tensile strain of 519 tons without permanent elongation – being twice the maximum strain to which it can be subjected in the bridge. The first testing machines made were themselves broken before the first bolts were proved to be defective. Among many curious accidents that occurred, was the breaking off of a piece of bolt 20 ft. long, and weighing more than half a ton, and shooting it "like an arrow" 60 ft. away; at the same time the recoil of the portion of the bolt still in the machine broke the piston rod from its fastenings, by reversal of the tension strain, and drove it clean out of the ram at the other end of the hydrostatic cylinder. Months were lost, and tens of thousands of dollars expended by the sub-contractors before the first bolt was made capable of sustaining a strain which it was next to impossible for machinery to impose. Up to the present time, 24 of the entire 50 required have been tested and accepted, of which 18 have gone to the Keystone Works to have the screws cut upon them. This result has been attained, after long delay, by trying new mixtures of steel, and exercising greater care in its manipulation.

Equally difficult, though in a different way, proved the manufacture of the steel tubes forming the arches of the spans, amounting to about 4-5ths of the entire steel required in the bridge. These tubes are to be 13 ft. long and 18 in. diameter, and they are each composed of 6 staves of the length of the tube, each $9\frac{1}{2}$ in. wide, and from $1\frac{1}{8}$ to $2\frac{1}{3}$ in. thick. The first rolls (made, of course, especially for this) proved defective, and weighing several tons, had to be removed to the shop, several miles distant. It was first attempted to roll them with the rib on each side, the staves projecting into the tube; but this was abandoned, necessitating the working of a new set of rolls, 12 in number, which went back to the shop two or three times before they turned out perfect staves. From these causes 6 months elapsed before the first stave was brought to the testing machine; and this done, the steel proved inferior. New mixtures of steel at length resulted in a perfect stave, and then the new difficulty was met, that staves made from the same formula had different degrees of strength, due, probably, to varying degrees of heat altering the proportions of carbon and iron. [The same had been true of the anchor-bolts.] This unfortunate result —experienced by a great loss of time and money to both the Keystone Company and the Butcher Works – led to investigation after some method, if possible, which would give an assured result with less skill and caution. Fortunately—providentially, one should perhaps say—Mr. Eads, before the contract with the Keystone Company was made, had his attention turned to the process of the manufacture of chrome steel, and to a thorough test of its capabilities, which had satisfied him of qualities eminently adapting it to bridge superstructure. Chromium, unlike carbon, is a metal; it has slight affinity, if any, for oxygen, and is not affected by heating. It forms an alloy with iron, from which heat does not expel it as it does carbon in "burnt steel." Chrome steel, according to the description, is more like steel than carbon itself. Beneath the rolls it works more smoothly, adapting itself perfectly to the form of the roll; and its products are very uniform in quality, being unaffected by variations in intensity of the heat. In 1869 Mr. Eads passed two entire days in a confidential inspection of the process of its manufacture, under the personal supervision of Mr. C. P. Haughian, Superintendent of the Chrome Steel Co., sole manufacturer under the patents of Mr. Bauer—assisted by Commodore J. W. King, Chief of the U. S. Bureau of Steam Engineering, and his own Chief Assistant, Col. Flad. Though thoroughly convinced of its superiority, indeed, of its adaptation alone among known varieties of steel to the demands of this structure, he could not under the contract stipulate for its use by the Keystone Co., whose privilege it was to open the sub-contract to competition among steel makers, several of whom declared their ability to furnish the required product. He was the more ready to do this, inasmuch as he had also, while in Europe, in the course of a personal examination of the establishments of Krupp and Peten Godet, received assurances that the requirements of this bridge could be met with carbon steel. The result of all is, that the Wm. Butcher Co. have now secured the right to use the chrome steel for the bridge; and during September 100 trial staves were made from Mr. Haughian's formula and under his direction—all beautifully and perfectly rolled, and all bearing the requisite test. With the decision to use this product exclusively hereafter, Mr. Eads considers the chief difficulty in the way of the reasonably early completion of the bridge surmounted. The bars produced have a tensile strength in excess of the specifications; while under compression the resisting power of the chrome steel may be indefinitely increased (in hardness even beyond cutting power of any lathe) by the addition of chromium.

IRON WORK.—Of scarcely less interest are the skewback plates, sunk in the face of the abutments, against which the ends of the steel arches are placed, and which sustain their entire thrust. These plates, 48 in number, are 7 ft. long, 3 ft. wide, and 6 in. thick, and are made of wrought iron. They are secured to the masonry by the anchor-bolts referred to above, $5\frac{3}{4}$ in. diameter. These bolts, 4 in the lower and 3 in the upper skewbacks, sustain no portion of the weight of the arches; their province is simply to prevent any displacement of the ends of the arches which might otherwise occur from wide variations of temperature, unequally distributing the weight imposed on the arches. Finally, difficulty has been experienced by the sub-contractors (under the Keystone Co.) in making the main braces connecting the upper and lower members of the arches, and second in importance only to the steel tubes of the arches themselves. Under the specifications, these braces (of iron) were to be tested to a tensile strain of 60,000 lbs. per sq. in. The iron thus far furnished under the sub-contracts has failed at from 48,000 to 54,000 lbs. Assurances (based on tests) are now given, however, that iron of the requisite quality will speedily be furnished.

COST OF THE WORK.—The original estimate, including land damages, was $4,686,475.44; the total expenditures to Sept. 1, 1871, amounted to $3,616,560.99; the additional amount required to complete the bridge is $1,949,497.17; making the entire cost of bridge and approaches $5,566,058.16—an excess of $1,479,582.72. It has since been found, however, these estimates are about $1,179,000 too low; the excess of the actual cost of the work over the estimates being satisfactorily accounted for by Mr. Eads.—*Iron Age.*

BORING of mining shafts is an ordinary operation in Germany and France, when the want of cohesion or the abundance of water in the ground prevented the adoption of the ordinary method of sinking and securing the shaft by either timbering, masonry, or iron tubtings. In Westphalia, the coal measures are, as a rule, covered to a certain depth, which increases toward the northward, by thick beds of marl belonging to the chalk formation. Though these beds often contain very much water, they are generally sufficiently coherent to confine the water between certain strata, and to allow the gradual sinking and excluding of water by water-tight tubtings or other means, until the coal measures are reached, which are generally pretty free from water. At the Dahlbusch mine, however, the marl was so much intersected by vertical fissures, that there was no hope for isolating the water of the various strata which had to be passed through, and it was resolved to bore, by means of steam engines, two shafts, the first of 2 metres, the second of 4.39 metres diameter, and both of 50 fathoms depth. When both shafts had reached a stratum of marl, considered to be sufficiently compact and water-tight, a column of cast-iron tubtings, weighing in the second instance not less than 420 tons, was gradually sunk down upon the bottom, so that between the tubting and the wall of the shaft an annular space was left, which was filled up with concrete, and so effectually excluded the water, that the bottom appeared dry after the water had once been emptied out, while during the boring operations 12 cubic ft. of water per min. rose from the shaft's opening. The total cost per 1 fathom depth was £135 for the narrow air-shaft, and £292 for the principal shaft. It is, however, very probable that the cost and time would have been very much less, if, instead of boring the shafts, compressed air, in combination with cast-iron tubtings, had been employed from the very beginning in sinking them after the usual method.

THE SUTRO TUNNEL REPORT.—The report of the Commissioners sent by the Government to investigate, and report upon the feasibility and true merits of the Sutro tunnel, and upon the expediency of extending Government aid to the enterprise, has been submitted to the Senate. The following vague abstract from it was transmitted some time ago by the telegraph:

"The Commissioners report that the tunnel is entirely feasible, and may be constructed in less than $2\frac{1}{2}$ years, at a cost of about $4\frac{1}{2}$ millions. They believe that the Comstock lode is a true fissure vein, continuing down indefinitely, and express the opinion that while the tunnel is not a necessity for ventilation or draining, yet any scheme which promises increased economy in the working of the mines and rendering valuable a vast amount of now worthless low-grade ores in the Comstock lode, becomes of national importance. Whether the Sutro tunnel project fulfils this condition of economy depends on the efficacy of the methods now employed in Germany and other countries of Europe for the concentration and profitable working of low-grade ores. On this point the Commission has not, in this country, by personal investigation, been able to obtain the desired information. In conclusion, the report commends the Sutro tunnel to favorable consideration, as an exploring work for deep mining.

BOOK NOTICES.

PRACTICAL GEOMETRY. By E. WYNDHAM TARN, M. A. London: Lockwood & Co.

This is a manual for the practical man, whether architect, engineer, or mechanic, and contains simple rules for the delineation of various geometrical figures employed for useful and ornamental purposes. No demonstrations of the rules laid down are given, the object of the author being to avoid all abstruse formulæ or complicated methods, and to enable persons with but a moderate knowledge of geometry to work out the problems required. Besides the ordinary figures described with straight lines, angles, and circles, there is abundant information on the ellipse, hyperbola, parabola, the catenary, the harmonic curve, the lemniscate, spirals, the involute of the circle, the lituus, and cycloids, the various rules being illustrated by beautifully worked wood-blocks, 164 altogether.

NOTES ON THE THEORY OF THE STEAM-ENGINE. By J. H. COTTERILL, M. A. London: E. & F. N. Spon.

The author of this little pamphlet says that the only English work on the steam-engine based on the true theory of heat is Rankine's "Steam-Engine and Other Prime Movers;" but on account of the very difficult form in which many parts of the subject are presented in the work in question, the "Notes" which form the subject-matter of this pamphlet were drawn up to assist the students of the Royal School of Naval Architecture and Marine Engineering, and they are now published in the hope of assisting those who are puzzled by the abstruse manner in which the theory of heat has hitherto been treated. Students of the subject will obtain useful hints from a careful perusal of these "Notes," and a clearer understanding of a theory not by any means remarkable for the perspicuity of its treatment in standard treatises.

LESSONS IN ELEMENTARY ASTRONOMY. By R. A. PROCTOR, B. A. London: Cassells.

Our readers are so well acquainted with the products of Mr. Proctor's pen, and his facile method of teaching scientific truths, that we need not occupy our space with any lengthy remarks on the little book before us. Suffice it, then, to say that these lessons are written in his usual concise style, and form an excellent stepping-stone to a knowledge of the "grand science." The work is abundantly illustrated, the drawings being to scale where possible; and the chapter on the fixed stars will enable any one to find the objects described.

A PACKET OF ASTRONOMICAL PLATES. Bickley, Kent: G. F. Chambers.

We have received from Mr. G. F. Chambers a bundle of astronomical plates, 50 in number, but containing altogether 108 engravings. These comprise representations of sun-spots, the various planets, eclipse phenomena, comets, double stars, star clusters, and nebulæ, the two latter being printed in blue ink, and all beautifully engraved and worked. Those who appreciate the assistance that young astronomers derive from well-executed drawing of telescopic objects will agree with us that this "packet" is worth the money for which it is offered.

SCALES FOR THE READY COMPARISON OF BRITISH METRIC WEIGHTS AND MEASURES. Arranged by A. L. NEWDEGATE, M.A. London: E. and F. N. Spon, 48 Charing Cross.

In the dozen scales which Mr. Newdegate has arranged may be readily found, by any one who has had a little practice with them, the value of any weights or measures of the metric system corresponding to those of our own. The scales possess all the advantages of the most elaborate tables, with the additional one that the proportion between the relative quantities is perceived at a glance. They comprise measures of length, area, solidity, and capacity, together with the reduction of fractional parts of different measures to their corresponding decimal value. Similarly to all methods of performing arithmetical problems without actual calculation, the degree of accuracy which can be obtained depends upon the more or less minute attention bestowed upon the scale. For approximate results, sufficiently accurate in many instances, one operation suffices to give the answer required. When greater precision is desirable, a second or supplementary operation is needed; but in any case the great labor that would be involved by a numerical calculation is entirely obviated. The engineer and architect, especially those who are engaged in designing works where metrical dimensions are used, will find these scales exceedingly valuable in the office. The use of them can be at once understood from the simple directions attached to them, and they, moreover, are presented in a form with which all professional men are well acquainted. The figuring and lettering are both clearly done, and the material is a good stiff card-board, which will stand the wear and tear of an office, which is sometimes no trifle.—*Engineer.*

COLLEGIATE ATLAS. London, Glasgow, and Edinburgh: William Collins, Sons & Co. For sale by Van Nostrand.

Contains thirty-two maps of modern geography, and eighteen maps of historical geography.

The maps are finely colored, and the volume is of suitable size for library shelves.

WHAT ARE THE STARS? By M. E. S. LYLE. London: G. T. Goodwin. For sale by Van Nostrand.

This is a collection of pictures, one hundred in all, of the constellations, beautifully printed, with white stars on black ground. The explanatory text gives full directions to the student for finding the stars of first and second magnitudes.

THE ROYAL INSTITUTION: ITS FOUNDER AND ITS PROFESSORS. By Dr. BENCE JONES. London: Longmans, Green & Co. For sale by Van Nostrand.

Contents: The Life of Count Rumford before the foundation of the Institution. II.—His life after the foundation of the Institution. III.—The early history of the Institution, and the life of Professor Garnett. IV.—The progress of the Institution to the resignation of Prof. Young, with the life of Dr. Thomas Young. V.—Progress of the Institution to the time of Faraday. VI.—Original papers relating to the American war. VII.—Original letters from Dr. Young. Income and expenditure of the Royal Institution to 1814.

THEORY OF HEAT. By J. CLERK MAXWELL. London: Longmans, Green & Co. For sale by Van Nostrand.

This is the seventh of the series of "Text-Books of Science." It presents a thoroughly scientific exposition of the laws governing all the phenomena of heat, so far as at present known.

The ordinary illustrations have been omitted, in order that the definitions and principles might be stated in the fullest manner.

Entirely unlike either Stewart's or Tyndall's works in the same department of physics, it is as valuable in its way as either. Indeed, it forms a good supplement to Tyndall's "Heat as a Mode of Motion," inasmuch as, comprehending all the phenomena so delightfully illustrated there, Prof. Maxwell has summed up in the most concise manner our present science of heat.

RESEARCHES IN THE CALCULUS OF VARIATIONS. By J. TODHUNTER, M.A., F.R.S. London and Cambridge: McMillan & Co. For sale by Van Nostrand.

Students who delight to labor in the higher fields of mathematical research, will gladly receive this essay from the hands of so accomplished an author.

The previous contributions of Mr. Todhunter to theoretical as well as applied science have been of the most valuable kind, and probably many students who have become familiar with these earlier works will be tempted to venture upon a new field, when thus offered the guidance of so well-known a master, and thus conquer a difficulty which, if presented by other hands, they would have shunned.

Education and Status of Civil Engineers in the United Kingdom and Foreign Countries. London. For sale by Van Nostrand.

This sets forth the conventional requirements for the profession of engineering in European countries. The regulations of the technical schools, their courses of study, and the conditions of graduation, are fully set forth. The work is of special value to instructors in scientific schools everywhere.

The Journal of the Iron and Steel Institute. London: E. and F. N. Spon. For sale by Van Nostrand.

This excellent journal appears as full of valuable information as ever. The Donk's Rotary Puddler receives a fair share of attention, both in the text and plates.

MISCELLANEOUS.

A cement to resist sulphuric acid, it is reported, may be made by melting caoutchouc by a gentle heat, and adding from 6 to 8 per cent. of the weight of tallow, keeping the whole well stirred. Then mix in enough dry slaked lime to make the whole of the consistency of soft paste, and finally add 20 per cent. of red lead, whereby the mass, which would otherwise remain soft, becomes hard and dry. This cement, it is asserted, resists boiling sulphuric acid. A solution of caoutchouc in twice its weight of raw linseed oil, aided by heating and the addition of an equal weight of pipe clay, yields a plastic mass, which also resists most acids.

In France, where the process of electroplating is regulated by law, every manufacturer is required to weigh each article when ready for plating, in presence of a comptroller appointed by the Government, and to report the same article for weighing again when the plating has been done. In this way the officer shows to the fraction of a grain the amount of the precious metal that has been added, and puts his mark upon the wares accordingly, so that every purchaser may know at a glance just what he is buying. In ordinary plating 1½ oz. of silver will give to a surface a foot square a coating as thick as common writing paper; consequently, when silver is worth $1.25 per oz., the value of the silver covering a foot square would be about $1.87. At this rate, a well plated tea or coffee pot is plated at a cost in silver of not more than $1.50 to $2; and the other expenses, including labor, would hardly reach more than half that amount. Electro-gilding is done in like manner. The gold is dissolved in nitro-hydrochloric acid, washed with boiling nitric acid, and then digested with calcined magnesia. The gold is deposited in the form of an oxide, which, after being washed in boiling nitric acid, is dissolved in cyanide of potassium, in which solution the articles to be plated with gold, after due preparation, are placed. Iron, steel, lead, and some other metals that do not readily receive the gold deposit, require to be first lightly plated with copper. The positive plate of the battery must be of gold—the other plate of iron or copper. The process is the same as that above described. The very best electro-gilding does not necessarily add a great deal to the cost of the article plated. A silver thimble may be handsomely plated so as to have the appearance of being all gold for 5 cents, a pencil-case for 20 cents, and a watch case for $1.—*Iron Age.*

Sir H. Davy has observed that, "in general, the quantity of charcoal afforded by woods offers a tolerably accurate indication of their durability; those most abundant in charcoal and earthy matter are most permanent; and those that contain the largest proportion of gaseous elements are the most destructible. Amongst our own trees," he adds, "the chestnut and the oak are pre-eminent as to durability, and the chestnut affords rather more carbonaceous matter than the oak." But we know from experience, that red or yellow fir is as durable as oak in most situations, though it produces less charcoal by the ordinary process. The following table of the quantity of charcoal afforded by 100 parts of different woods is added, for the information of the reader:—

Kind of Wood.	Watson.	Mushet.	Proust.	Rumford
Oak, dry....	22.92	22.6	19	43
Chestnut...	....	23 2	....	....
Mahogany.......	20.82	25.4	....	....
Walnut..........	26.04	20.6	....	....
Elm.............	....	19.5	....	43 27
Beech.....	....	19 9	....	...
Fir....	15.62	....	....	44.18
Norway Pine.....	....	19.2	....	....
Pine.............	....	....	20	....
Scotch Pine.....	....	16.4	....	....
Ash.........	17.71	17.9	17	....
Poplar..........	....	....	....	43.57
Lime	....	....	....	43.59
Birch..	....	17.4	....	....
Sycamore........	...	19 7	....	....
Sallow..........	....	18.4	...	....

In Count Rumford's experiments a longer period was allowed for the process; and, in consequence, his results represent more nearly the real quantities of carbon in each wood than the others. But even according to the common process, it does not appear that the proportion of charcoal is a satisfactory criterion of the durability.

The article entitled "Graphical Estimates for Earthwork," in our January number, page 84, was written for the magazine by Arthur M. Wellington, C. E., Division Engineer of Michigan Midland Railroad.

An experiment to determine the comparative durability of different woods is related in Young's "Annals of Agriculture." Inch and a half planks of trees from 30 to 45 years' growth, after 10 years standing in the weather, were examined and found to be in the following state and condition:—Cedar, perfectly sound; larch, the heart sound, but sap quite decayed; spruce fir, sound; silver fir, in decay; Scotch fir, much decayed; pinaster, quite rotten; chestnut, perfectly sound; abele, sound; beech, sound; walnut, in decay; sycamore, much decayed; birch, quite rotten. This shows at once the kind that are best adapted to resist the weather; but even in the same kind of wood there is much difference in the durability, and the observation is as old as Pliny, that "the timber of those trees which grow in moist and shady places is not so good as that which comes from a more exposed situation, nor is it so close, substantial, and durable;" and Vitruvius has made similar observations. Also split timber is more durable than sawed timber, for the fissure in splitting follows the grain, and leaves it whole, whereas the saw divides the fibres, and moisture finds more ready access to the internal parts of the wood. Split timber is also stronger than sawed timber, because the fibres, being continuous, resist by means of their longitudinal strength; but when divided by the saw, the resistance often depends upon the lateral cohesion of the fibres, which is in some woods only $\frac{1}{10}$th of the direct cohesion of the same fibres. For the same reason whole trees are stronger than specimens, unless the specimens be selected of a straight grain, but the difference in large scantlings is so small as not to be deserving of notice in practice.

ADULTERATED CEMENT.—At a meeting of the Chemical Society of Newcastle, not very long ago, the President of the Society (Mr. John Glover) read the following statement, which calls for further publicity:—

"During the last few days I have learned that large quantities of blast furnace slag is being ground with Portland cement in this district, and as in the analysis of such cement great stress is very properly laid on its percentage of hydrated silicic acid, I have thought it well to draw your attention to the fact, as blast furnace slag, on being treated with hydrochloric acid, yields a large percentage of hydrated or gelatinous silica, although it has not the slightest value as a cement. You will see from what I have said that a chemist, proceeding to the analysis of a cement so adulterated, might be misled if he were not aware of such adulteration. As a proof that such adulteration is a fraud on the purchaser, I have caused the following experiments on the cohesive power of a pure cement, and of the same cement mixed with slag, to be tried:—The average of a number of bricks of pure cement carried a weight of 485 lbs., and broke with a weight of 492 lbs.; while the same cement, mixed in the proportion of equal parts of cement and slag, bore a weight of only 301 lbs. and broke with 308 lbs. A mixture of the same cement, in the proportion of three of cement to one of slag, bore 375 lbs., and broke with 382 lbs., and each brick was made in the same mould, and was allowed 7 days to harden. You will see from these tests that a purchaser of such cement will not be able to mix with it the same amount of sand as when he buys the pure article, as the slag already mixed with it has taken the place of so much sand, and is really of no greater value than sand, as bricks, mixed with sand in the same proportions as when slag was used, gave nearly the same results. If slag gives a better appearance or color to Portland cement, a fair trader should state the fact of its presence, so that his customer might know the price he is paying for such qualities. If our analytical chemists would undertake to test the physical properties of cement, such as cohesion, hardness, etc., as well as its chemical composition, they would supply a want, as there is no such public tester, at least in this neighborhood."

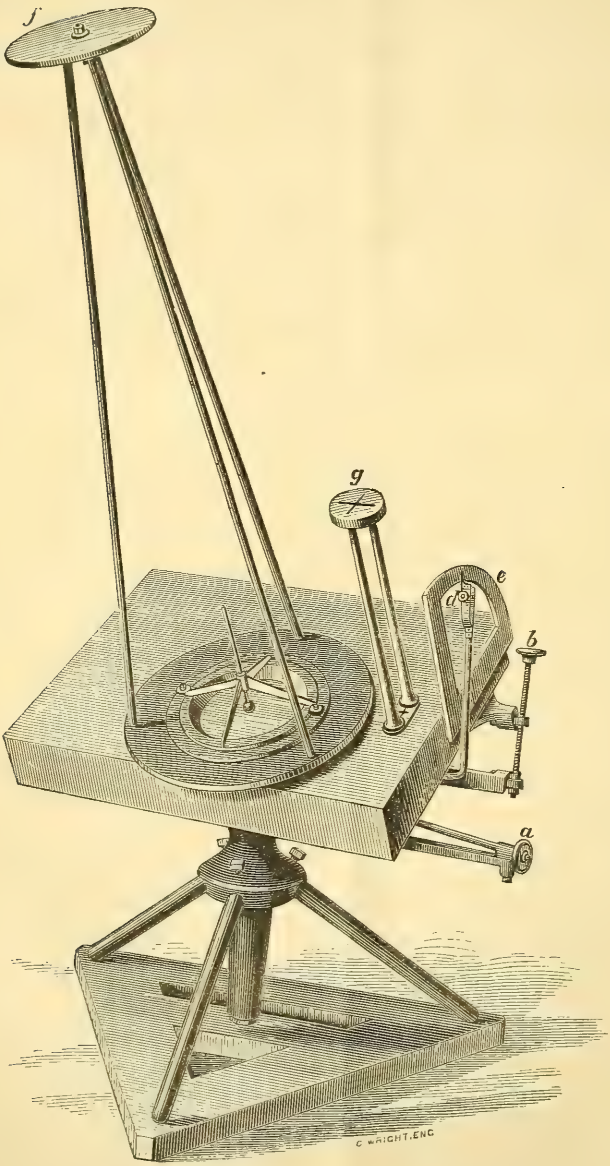
THE Taranaki iron-sand, one of the valuable mineral products of New Zealand, is again attracting considerable attention. A series of experiments undertaken under the direction of the Government apparently proves that steel of the highest quality can be produced at a *minimum* cost and by the most simple process. The iron-sand as taken from the beach is mixed with an equal quantity of clay and of the ordinary sea-sand, which contains a very large admixture of shell. These materials are worked up into bricks, which are hardened in a kiln, then broken up into irregular pieces, which are smelted in an ordinary cupola furnace. The product of this simple process is cast steel of the finest possible texture, from which some beautiful specimens of the finest cutlery have been manufactured. The experiments were conducted by a mechanic in the Government employ, who was restricted to an expenditure of £100, and was therefore only able to erect a furnace of the most temporary description. He, however, succeeded in producing at the first and only trial 5 cwt. of pure steel in the manner I have endeavored to describe, and his success seems likely to lead to further and more extensive efforts to utilize the almost inexhaustible deposits of this ore which exist at Taranaki and elsewhere.—*Times Correspondent.*

A PROCESS devised by Mr. Nagel, of Hamburg, for coating iron, steel, and other oxidizable metals with an electro deposit of nickel or cobalt, consists in taking 400 parts, by weight, of pure sulphate of the protoxide of nickel by crystallization, and 200 parts, by weight, of pure ammonia, so as to form a double salt, which is then dissolved in 6,000 parts of distilled water, and 1,200 parts of ammoniacal solution, of the specific gravity of 0.909, added. The electro deposit is effected by an ordinary galvanic current, using a platinum positive pole, the solution being heated to about 100 deg. Fahr. The strength of the galvanic current is regulated according to the number of objects to be coated. For coating with cobalt, 138 parts, by weight, of pure sulphate of cobalt are combined with 69 parts of pure ammonia, to form a double salt, which is then dissolved in 1,000 parts of distilled water, and 120 parts of ammoniacal solution, of the same specific gravity as before, are added. The process of deposition with cobalt is the same as with nickel.—*Iron Age.*

SOME careful soundings of the Baltic have been made by the steamship Pomerania. The greatest depth of the Baltic Sea between Gothland and Windau was found to be 720 ft. At the depth of from 600 ft. to 720 ft. the water was, at the end of July, very cold, the thermometer giving from $\frac{1}{2}$ to 2 deg. Reamur (near the freezing point of Fahr). No plants were found at this depth, and only a few specimens of one or two species of worms were brought up with the clay and mud.

Apparatus for Measuring the Radiant Heat Transmitted by the Sun's Chromosphere.

Constructed by CAPTAIN JOHN ERICSSON.



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THE SOLAR ATMOSPHERE.

By Captain JOHN ERICSSON.

From "Nature."

The object of the investigation discussed in "Nature" (No. 101, pp. 449–452) being merely that of ascertaining whether the incandescent matter contained in the solar atmosphere transmits radiant heat of sufficient energy to admit of thermometric measurement, no particular statement was deemed necessary regarding the spectrum which appeared on the bulb of the focal thermometer after shutting out the rays from the photosphere during the experiments. The appearance of this spectrum has in the meantime been carefully considered. Its extent and position suggests that the depth of the solar atmosphere far exceeds the limits hitherto assumed.

The accompanying frontispiece represents an apparatus constructed by the writer to facilitate the investigation.

Evidently the expedient of shutting out the photosphere while examining the effect produced by the rays emanating from the chromosphere, calls for means by which the sun may be kept accurately in focus during the period required to complete the observations. The main features of the apparatus being shown by the illustration, a brief description will suffice. The parabolic reflector which concentrates the rays from the chromosphere (described in the previous article) is placed in the cavity of a conical dish of cast iron, secured to the top of a table suspended on 2 horizontal journals, and revolving on a vertical axle. The latter, slightly taper, turns in a cast-iron socket, which is bushed with brass and supported by 3 legs stepped on a triangular base, resting on friction rollers. The horizontal journals referred to turn in bearings attached to a rigid bar of wrought iron situated under the table, firmly secured to the upper end of the vertical axle. The horizontal angular position of the table is adjusted by a screw operated by the small hand-wheel *a*, the inclination being regulated by another screw turned by the hand-wheel *b*. A graduated quadrant, *e*, is attached to the end of the table in order to afford means of ascertaining the sun's zenith distance at any moment. The index *d*, which marks the degree of inclination, is stationary, being secured to the rigid bar before described. The rays from the photosphere are shut out by a circular disc *f*, composed of sheet metal turned to exact size, and supported by 3 diagonal rods of steel. These rods are secured to the circumference of the conical dish by screws and adjustable nuts in such a manner that the centre of the disc *f* may readily be brought in a direct line with the axis of the reflector. The mechanism adopted for adjusting the position of the table by the hand-wheels *a* and *b*, requires no explanation; but the device which enables the operator to ascertain when the axis of the reflector is pointed exactly towards the centre of the sun demands particular notice. A shallow cylindrical box *g*, provided with a flat lid and open at the bottom, excepting a narrow flange extending round the circumference, is firmly held by 2 columns secured to the top of the table. A convex lens of 26 in. focus is inserted in the cylindrical box, the narrow flange mentioned affording necessary support. The lid is perforated by 2 openings at right angles, 0.05 in. wide, 2.5 in. long, forming a cross, the lens being so adjusted that its axis passes through the central point of intersection of the cross. The face of the table being turned at right angles to the sun, or nearly so, it will be evident that the rays passing through the perforations and through the lens will produce, at a certain distance, a brilliantly illuminated cross of small size and sharp outline. A piece of ivory or white paper, on which parallel lines are drawn intersecting each other at right angles, is attached to the top of the table in such a position that the centre of intersection of the said lines coincides with the axis of the lens. This axis being parallel with the line passing through the centre of the disc *f* and the focus of the reflector, it will be perceived that the operator, in directing the table, has only to bring the illuminated cross within the intersecting parallel lines on the piece of ivory. Ample practice has shown that by this arrangement an attentive person can easily keep the disc *f* accurately in line with the focus of the reflector and the centre of the sun during any desirable length of time. The absence of any perceptible motion of the column of the focal thermometer during the experiments which have been made, furnishes the best evidence that the sun's rays have been effectually shut out by the intervening disc, which, it should be remembered, is only large enough to screen the aperture of the reflector from the rays projected by the photosphere. It may be noticed that actinometric observations cannot be accurately made unless the instrument is attached to a table capable of being directed in the manner described; nor is it possible to measure the dynamic energy transmitted by solar radiation unless the calorimeter employed for the purpose faces the sun with the same precision as our parabolic reflector. It is worthy of notice that the lightness of the illustrated apparatus renders exact adjustment easy, since screws of small diameter and fine pitch may be employed. It only remains to be stated that in order to admit of accurate examination of the spectrum before referred to, the thermometer is removed during investigations which do not relate to temperature, a cylindrical stem of metal, 0.25 in. diameter, coated with lamp black, being introduced in its place.

With reference to the result of recent experiments, it is proper to state that, at the present time, the sun's zenith distance being now nearly 60 deg. at noon, no perceptible heating takes place in the focus of the parabolic reflector. The observations relating to temperature, mentioned in the previous article, were made when the zenith distance was only $\frac{1}{3}$ of what it is at present. The consequent increase of atmospheric depth, at this time, has completely changed the color of the spectrum, and rendered the same so feeble that its extent cannot be determined. As seen last summer, before the earth had receded far from the aphelion, the termination of the spectrum reached so far down that an addition of 0.15 in. to the radius of the disc *f* would scarcely have shut it out. Now an addition of 0.15 in. to the radius of the disc corresponds to an angular distance of 9 min. 45 sec.; hence, assuming the radius of the photosphere to be 426,300 miles, the depth of the solar atmosphere cannot be less than 255,000 miles. And, judging from the appearance at the period referred to, there can be little doubt that a larger and more perfect reflector will enable us to trace the spectrum still further down. Consequently, a further enlargement of the disc *f* will be required to extinguish wholly the reflected light from the solar atmosphere. It is reasonable, therefore, to suppose that the depth of the solar atmosphere will ultimately be found to exceed very considerably the foregoing computation.

It has been suggested regarding the instituted investigations of the radiant heat transmitted by the chromosphere, that the thermo-electric pile ought to be employed in combination with the parabolic reflector. The object of the investigation being simply that of proving by the feebleness of the radiant power transmitted to the surface of the earth that the chromosphere and outer strata of the sun's envelope do not possess radiant energy of sufficient intensity to influence solar temperature as supposed by Secchi, tests of the suggested extreme nicety are not called for.

With reference to the effect of increased depth, the small amount of retardation suffered by the rays in passing through the highly attenuated atmosphere of the sun, previously established, shows that the question of solar temperature will not be materially affected, even should it be found that the depth of the envelope is greater than the radius of the photosphere.

THE STRENGTH OF MATERIALS.

From "The Engineer."

We have for years persistently put before our readers the fact that nothing is so much needed for the advancement of engineering science as experiment. A great Irish political leader of the people once made "Agitate! agitate! agitate!' his watchword. In like manner we use the word "Experiment! experiment! experiment!" Nothing can be added to our existing stock of knowledge without it, and those who experiment most frequently and most thoroughly best appreciate the value of the practice. In nothing are we more deficient than in our knowledge of the properties of iron and steel. We have much yet to learn about steam and the steam engine; about fuel, about boilers, about ships, roads, railways, bridges; about stone, timber, and cement; about, in fact, every subject with which an engineer, civil or mechanical, has to do. But about nothing are we more ignorant than of the properties and qualities of iron and steel; and it is not difficult to find the cause of this ignorance. It results simply from the fact that the varieties of iron and steel in the market are almost endless, and the processes of production are numerous and diversified, while the record of experiments made with the materials under different forms, and produced and used in different ways, are comparatively few and far between. On the importance of possessing accurate information concerning the properties of materials used in construction, we need not dwell. Every one admits it; but, unfortunately, the number of those who endeavor, by direct experiment, to increase their knowledge of the subject, is as yet extremely limited. This is not as it should be, and it is with a strict regard for the best and truest interests of science that we wish here to call the attention of our readers to the fact that in the heart of London there may be found a very modest establishment, conducted by a gentleman whose principal fault is that he refrains from putting his work more prominently before the eyes of the world, where more may be learned about the properties of iron and steel in a few hours than can be acquired by any amount of study, or by years of practice with these materials in construction. We speak of Mr. Kirkaldy's testing works in Southwark, and we propose here to say something of what Mr. Kirkaldy has done and is doing. Several years have elapsed since he published a treatise on the "Strength of Iron and Steel," which at once made him, in a sense, famous. His extraordinary care and foresight enabled him, with comparatively imperfect apparatus, to obtain a series of experimental results, which, in a manner, revolutionized existing theories on the subject. But the author of this work was not slow to perceive that, with improved appliances, he could extend his range of observation, and obtain still more valuable results. He spent two years in investigating the principles which should be observed in the construction of a thoroughly efficient testing apparatus, and two more in working out the details. The result may be seen in the magnificent testing machine at his establishment in Southwark. It forms no part of our purpose to describe this machine in detail. It will suffice to say that in order to get over a difficulty constantly urged against testing machines, to the effect that different apparatus gave different results, Mr. Kirkaldy designed a machine capable of breaking a heavy girder, or a ½ in. bar; of pulling asunder a thin wire, or the shank of a best bower anchor; of crushing a great cube of cast iron, or a common brick, and yet in all cases giving results strictly comparable and accurate. This machine has been in constant operation for over 6 years, and Mr. Kirkaldy holds, in the light of the experience acquired during that space of time, that it is impossible to introduce any substantial improvement. As to its capacity for work, it will suffice to say that it can exert either a compressing or tensional strain of over 350 tons, with perfect safety. It will take in bars or columns of greater length than are generally used in construction, and it will test girders for transverse strain of any depth, and any length up to 30 ft., provided they are not more than 13 in. wide, measured across the flanges, the length between the supports while under test being 26 ft. The arrangements for measuring and recording the stretch and load on any specimen are extremely simple and ingenious, and heavy as the machinery is, the finish is so good, the knife edges so accurate, and the motion of the more massive portions so slow and so easy, that practically perfect accuracy is obtained.

But it is not our object so much to speak of Mr. Kirkaldy's testing machine as of the work he has done and is doing. Unfortunately, as we have stated, the value of his labors is not yet fully appreciated, and engineers and ironmasters are still slow to avail themselves of the facilities for acquiring information which he places at their disposal. Within the last few months, however, the Barrow Hematite Company, the Russian, and the Italian Governments have each put up a machine constructed under Mr. Kirkaldy's patents, but each only 1-4th of the power of the Southwark apparatus. Still this is a step in the right direction. We are happy to add that the Indian Government, alive to the advantages that can be derived from the testing of materials, have given Mr. Kirkaldy a contract for the examination of all the materials to be used on the new Indian railways. One of the first steps taken by Mr. Kirkaldy was to prepare a table for the Indian Government, in which various qualities of iron are classified under different letters. Thus, first quality iron must comply with one set of conditions, second quality with another, and so on. The Government have then actual figures to go on, the purchasers know what they ought to get, and the sellers what they are expected to supply, and no chance of dispute can arise. Thus, for example, plate iron in Class D must sustain a tensile strain of 23 tons per sq. in., and elongate 15 per cent. with the grain, and 9 per cent. across the grain. This is not a hard-and-fast rule, however, for if the iron broke with 22 tons, yet elongated 16 per cent., it would not necessarily be rejected. If, on the contrary, it stood 24 tons, but elongated only 12 per cent., it would not be considered to comply with the conditions. The first error would be on the safe, the second on the dangerous side. A glance at Mr. Kirkaldy's museum of specimens will show that the application of his tests has proved of the greatest utility. We shall not refer to any particular instances as regards the Indian railways, but it will prove interesting to give here a few examples of the work recently done by Mr. Kirkaldy and the results he has obtained.

A very large roof was not long since erected over an important railway station. The span is not much less than that of St. Pancras roof, but the construction is totally different, heavy wrought-iron flat tie bars being used to take the thrust of the principals. Nineteen samples of these links were selected at hap-hazard and sent to Mr. Kirkaldy to be tested. It was understood that the links were all to be of excellent iron. A proportion, however, of those tested were no better than puddled bars. It would be hardly fair to blame the manufacturers for this. No doubt they believed that they were supplying good iron, but such is the general ignorance of ironmasters of the properties of good iron, or the best methods of obtaining it, that, as we have said, bars little better than if they had been rolled off straight from the bloom were sent in. Of the many hundred tons used in the structure, of course the greater proportion must have complied with the specification; but the fact that even a few bad bars got among the rest shows how invaluable the system of test is. As an example of the value of practical tests, we may cite another instance. Two or three heavy links for the chains of a suspension bridge were recently tested by Mr. Kirkaldy. These had large flat eyes. In every case the iron, which was of fair quality, tore asunder through the eye; and a very simple calculation proves that these links, which were designed by an eminent engineer, if strong enough in the eye, have no less than 18 per cent. too much iron in the body. When we consider the important part played by the chains of a suspension bridge, it will be seen that this error is one of enormous proportions, entailing great additional cost in the structure, and absolutely introducing an element of weakness in the shape of 18 per cent. extra weight, which it was highly desirable to avoid. If the designer of the links had taken the trouble to get half a dozen of various proportions made and tested, he would, at the outlay of a few pounds, have ascertained what was the proper shape to give his chain links, and hundreds, if not thousands of pounds would have been saved by the experiment. One more example of the value of such tests and we have done. A railway company, much troubled by the breakage of axles, ordered a lot of round charcoal bars, to get over the difficulty. These on examination did not appear of very good quality, and one or two, taken at hap-hazard, were sent to be tested. But a single experiment was required to prove that there was not a particle of charcoal iron used in carrying out the order if the sample was a fair specimen, as no doubt it was, of the lot. Here again we have a case where the outlay of a few pounds, beyond question, averted an accident which might have cost the railway company some thousands. Before leaving this portion of our subject we must narrate a little anecdote which Mr. Kirkaldy tells with no small humor. Certain individuals, who shall be nameless, applied some time since to the Government, stating that they had discovered a chemical process by which the strength of cast iron could be augmented 20 per cent. The authorities asked for proof, and refered them to Mr. Kirkaldy to supply it. So one day a cart was driven up to Mr. Kirkaldy's door, in which lay two bars of cast iron about 6 in. in diameter and a couple of feet long. The tensile strength of these Mr. Kirkaldy was asked to test. He was told all the circumstances. One of the bars was good ordinary cast iron, the other was made by the new process. The common bar was first put into the machine and broken; the results were registered. The second bar was then put in and the owners watched with anxiety till a similar strain had been put upon it. They then requested to be informed when a strain of 20 per cent. greater than that which broke the common bar had been reached. As the pumping went on, their excitement became intense; 15, 18, 20 per cent. was reached. The moment the latter point was attained they called on Mr. Kirkaldy to stop. This, however, he refused to do, notwithstanding frantic protestations on the part of the owners that they did not want their bar broken. Mr. Kirkaldy assured them that it was "a point of honor with him either to break any specimen put into his machine or the machine itself." In a moment more the bar broke. The section was remarkable. In the centre was a wrought iron bar about 2 in. diameter, and arranged near the edge were 6 ½ in. round bars all cast into the block, and partially converted into steel by the action of the hot cast iron! Of course the intention was to obtain a certificate from Mr. Kirkaldy that the improved (?) cast iron bore more than the common iron by 20 per cent. The breakage of the bar defeated the fraud. This strange story is literally true, and Mr. Kirkaldy has one half of the compound bar in his museum to verify its accuracy.

But it is not to be supposed that Mr. Kirkaldy's labors are confined to testing iron. His work includes every conceivable material of construction. His recent experiments with steel tires are especially valuable. It would be impossible, within reasonable limits, to detail these experiments, but we may mention one interesting fact. Some time since a steel locomotive tire broke, and a good deal of mischief was done. Small specimens cut from the broken tire were sent to him for examination. No two gave the same fracture, and the engineer of the line stated his conviction that the reason lay in some defect in the system of test. To this Mr. Kirkaldy replied that the true cause lay, not in the machine or system of test, but in the want of homogeneity in the tire, and he undertook to demonstrate this if he were supplied with larger test bars. This was done, and the facts came out exactly as Mr. Kirkaldy stated. We ourselves examined three broken specimens. One had a close tool steel fracture; another, a tough, almost fibrous, fracture; while the third specimen showed both, the line of demarcation across the bar being clearly defined. Here a very few experiments proved beyond all question, to what cause the breakage of the tire was attributable. Mr. Kirkaldy has recently experimented with some very remarkable specimens of soft Bessemer steel made by the Bolton Iron and Steel Company, circular discs of steel $\frac{5}{8}$ in. thick and 12 in. diameter being forced through an orifice 10 in. in diameter into the form of a cup 3.38 in. deep, the pressure required to perform this feat amounting to 294,350 lbs., or 131.4 tons.

We have stated that Mr. Kirkaldy's experiments are not confined to iron and steel. He has, on the contrary, carried out some most valuable investigations on the strength of building materials, alloys, springs, india-rubber, tubes, malleable cast iron, belting, and ropes; but of these we cannot speak at present. We shall return to the subject. Meanwhile, we may add that Mr. Kirkaldy's museum is open to any engineer interested in the strength of materials ; and we can assure our readers that they will find in its glass cases much food for reflection, and convincing proof that about the strength of materials we have one and all a great deal yet to learn.

WATER METERS.*

By F. E. BODKIN, Esq.

The question of measuring water supply by meter has for a great many years been occupying the attention of engineers. Ever since 1824 a yearly increasing number of inventions bearing upon this important subject, and amounting at the present time to a total of 313, have been brought before the public, in which are included patents taken out in England and communications from foreign engineers which have been registered at the Patent Office ; yet, with all this great expenditure of ingenuity, it is generally allowed that there is no meter at present in really practical use which may be considered an accurate, or, in many ways, a satisfactory machine.

If we take a review of the time which has elapsed since 1824, when I stated the first patenting of a water meter is on record, we find that up to the year 1851, a period of 27 years, 30 different inventions had found their way into public notice ; whilst during the 10 years succeeding, or up to 1861, no less than 90 ; and again, from 1861 to 1871, or the present time, 193. I do not mean to say that all these were for separate and entirely different machines ; the larger proportion were so, but a great many only specify certain improvements in previous inventions, or apply them to particular uses, a process which frequently implies the production of a practically new instrument.

There could be no better argument than the above statistics found in proof of the general demand for a good water meter, since all invention is necessarily the result of some extensive public requirement. We may also adduce the fact that, unsatisfactory as are all the meters at present supplied to the public, they have, at least those amongst them which present fewest defects in working, met with liberal customers among the water companies and private individuals, who are willing, at much personal inconvenience and expense, to refer the estimate of their supply of water to the arbitration of these meters. In large factories, for instance, or in the case of machinery driven by water or steam power, and large stabling establishments, hotels, and even the better descriptions of dwelling-houses, it has been found an advantageous arrangement, and examples are enumerated by advertisers of water meters, pointing out the benefits likely to accrue to their purchasers, either on one side or other of the meters, from their use. For instance, a sum of £40 per annum paid in one case for water, rose no less than £1,000 in favor of the suppliers after the introduction of a meter. We may view the matter in another light, by comparing our dealings with water supply with our management of gas, not that the cases are in all respects similar, for gas is a luxury, hardly yet a necessity of life, whereas pure wholesome water is, in the truest sense of the word ; but gas is, viewed scientifically, a very similar material to deal with, and is supplied by volume through pipes, and is turned on and off

*A paper read before the Society of Arts.

as required, and measured and paid for by meter. Moreover, by comparison of equal volumes, we find that water is the more expensive commodity of the two, which is an additional argument favorable to the use of water meters under certain conditions, even though there were more difficulty and expense in obtaining them.

If, instead of viewing the extreme cases I referred to above, we consider in a more extensive aspect the question whether the invention and use of a good water meter would be advantageous to householders and other consumers alike, one cannot but feel that the present system adopted for the general public, of payment according to the ratal or means of each separate consumer, is a most wise and liberal arrangement, hanging the chief burden of expense on the wealthier classes, and supplying an equal necessary of life to the lower orders at greatly reduced cost. Nor would the introduction of meters necessarily relieve any particular class, since the same expenditure would have to be defrayed as our requirements of proper purity and supply at present entail on the several water companies, whilst it would certainly act very prejudicially to the appearance and health of the "great unwashed" of our large towns, who would be only too anxious to reduce their water bills to a minimum. Perhaps, however, with the introduction of constant supply the general use of water meters might become an advantage—almost a necessity—to prevent waste; but in London, where this would be most severely felt, constant supply is, as yet, only a very remote possibility.

There are also other uses to which water meters may be applied, such as calculating the supply of water to steam boilers, for the purpose of ascertaining their evaporative power ; also the expensiveness generally of water and steam power, a means of accurately judging which would enable the engineer, with far greater facility, to arrive at their comparative excellencies.

The great difficulties which surround the designing of a good water meter must excuse the ill success, so far, of inventors in meeting this demand ; these may be better judged of by a short statement of some of the offices required of such a machine.

Firstly, a water meter should register with accuracy, that is, within 1 per cent. of the truth ; and this, it must be remembered, not under a uniform rate of flow of the fluid, but under every possible variation of pressure—from a head only of a few feet, up to 200 or 300—unless, indeed, it be intended to act as a low-pressure meter, to some of which I shall call attention presently, and also under any ordinary variations of temperature.

Secondly, it ought to be of sufficient strength throughout to stand these high pressures, and even sudden alterations and blows under them, which form a still more trying ordeal.

Thirdly, it is very requisite it should be cheap, both in original cost and to maintain in repair subsequently. This latter consideration is very important, as under high pressures any bearing surfaces would be travelling at a great speed, and, even with the common impurities of water, would be liable to wear away very fast.

Fourthly, simplicity, both in number and shaping of parts, chiefly because all water meters are liable to get soon clogged with a muddy deposit, and require cleaning, and any complicity renders this operation difficult and expensive ; it also naturally infers great costliness in repairs when the machine gets out of order, a defect to which such would be particularly liable.

It also often happens that a meter may be left unused for a time, and the working parts become dry. This should not interfere with the accurate working of the machine on its again coming into use ; it is also greatly to the advantage of any meter that it should be uninjured by the entrance of heated water or steam, when supplying steam-boilers or other machinery, where such are used ; that it should form a closed valve against the return of water already passed through it ; also that the register and work should be out of reach of interference of people desirous to tamper with them ; and, a very important consideration, that there should be as little loss of head or decrease of flow as possible in the water during its passage through. There are also peculiar excellencies, if we may believe the statements of advertisers, which recommend some meters for use in private dwellings, far in preference to others ; for instance, a certain Frenchman, with the ardor of competition so peculiar to our neighbors, describes his invention as not only a perfect meter, but a useful and elegant ornament for a gentleman's hall or drawing-room.

When we come to consider more carefully the leading features of all this vast mass of invention, we find that it is mainly directed to the measurement of water under two different conditions, low and high pressure; low pressure, where the water is delivered from the meter entirely free from momentum; and high pressure, where the water arrives at, passes through, and leaves the meter at the same, or nearly the same velocity. Low-pressure meters were in use some time before the introduction of the other description, are much more simple in design, and can be made to register with perfect accuracy, but they have now fallen into disuse, except in special cases, where a careful measurement, generally of some fluid more valuable than water, is required, irrespective of the time occupied in the process. It will be worth while to notice briefly the various ways in which this has been accomplished.

In the most simple method graduated glass tubes are used in connection with a barrel or vat, or closed chamber, and by which the amount of fluid run off can be easily read. Another, almost as simple, consists in the use of a measure-chamber in connection with an ordinary tap; the tap is at one end, and a valve at the other, or feed end of the chamber. These are so connected that one turn of the tap handle allows the water access to the chamber, and closes the outlet; the reverse action closes the inlet valve, and allows the measured quantity to escape for use; each turn of the handle is registered. The principle is applied in many ways, some constructing the measure-chamber large enough for a considerable supply.

A third makes use of a large vessel of known capacity, generally an upright cylinder, and places a valve on a properly fitted seating at the lowest part; there are also floats in the vessel, and while the valve is closed and the water rising, the float also lifts, and in doing so actuates lever arms, which by ordinary mechanism shift the valves when the vessel is full, the lower valve from its seating, and a cut-off valve attached to the inlet pipe. One means whereby this is attained is by hanging a weight from the float over a pulley, fixing a cam on to the shaft of the pulley, and causing the cam to raise a long lever arm at one point of its revolution. As the arm rises and falls, it moves the valve. The float when out of water, being heavier than the weight, falls with the water and reverses the valves at the bottom; a register tells the number of rises and falls that have taken place.

A fourth group of inventions places two tanks side by side, or subdivides one by a central partition; in each there are valves at the lower ends, and each contains a float. In one case a system of siphons is substituted, the supply-pipe is placed over the partition, and alternately made to direct its flow into one or the other subdivision; the float rises in each alternately, and, in most cases, by a central axis, which they actuate by lever, change the direction of inlet, and raise their own outlet valves; the central axis has weighted arms attached, to insure the instantaneousness of the action.

According to another device, a subdivided trough is centred on trunnions, and caused to tilt or tumble over from one side to the other by the weight of water which has flowed into each division of it from a fixed inlet; the trough is generally made triangular in section, and so proportioned and centred that it shall not tilt until each division is quite full; the number of tumbles is registered in this case.

A further modification of the above arranges a number of these tumbling buckets round a centre spindle, their continual filling and tilting causing the spindle to rotate. Sometimes they are made to work in a water level, each bucket gradually sinking down to it. But when fixed, free to revolve, they are arranged so that each weight of water must overcome the resistance offered by an arm of a weighted lever, which comes in contact with a catch attached to each bucket, and will not allow it to pass until out-weighted. The revolutions are registered, and represent in amount so many buckets full each.

A very novel idea is to measure, by means of a gas meter of ordinary construction, the amount of air exhausted from any closed chamber from which the liquid is allowed to run, the amount of water extracted being taken as equal to that of the air registered.

Endeavors have been made to convert several of the above into high-pressure meters, by making them of sufficient strength, and causing them to work without loss of head by air compressed in suitable chambers.

From this brief account it will be readily understood that water can be measured by low-pressure meters with the greatest accuracy, but they are entirely useless for supplying large quantities at any speed. They always require the intervention of a cistern of some considerable capacity placed high up; and in large establishments a separate meter would be required for every cistern. They may, in fact, be considered quite inadequate to the requirements of modern water supply.

Among high-pressure meters a greater variety exists; they may be divided into two principal classes, those which give a positive registration of actual quantities of water, and those which register by inference from the flow or pressure of the water passing through them.

Amongst positive high-pressure meters various arrangements of piston and cylinder hold the first place. The principle of these meters is to enclose in a hollow carefully-bored cylinder of known capacity a piston free to move from end to end by the pressure of the incoming fluid, the piston being caused by this force to drive out the quantities of fluid already measured. This motion, and its degree of perfection, will depend mainly on the arrangement of the valves which regulate the inlet and outlet of the liquid.

In the simplest form, the piston, very carefully packed, is fitted with a long piston-rod, protruding from a packing box at one end of the cylinder, and bearing one or two catches, which, just as the piston reaches the top or bottom of its stroke, come into contact with, or strike against, the ends of levers, causing the valves to shift; or the same is effected by a roller on the piston-rod running up and down in a slot in a bar of metal, and striking each end in turn; the bar, on receiving the blow, throws over a weighted lever, which alters the valves; or, by some, a rack is used attached to the top of the piston-rod; this gears with a pinion on a fixed shaft, two catches are fixed on each side of the pinion, and these alternately throw over a weighted lever from side to side; the weight in falling turns a four-way cock. This last is a device used by Mr. Kennedy, in his patent water meter, one of the first ever brought into use. It possessed the advantages over others of the same time, that it allowed a continuous stream of water to pass without serious loss of head, and registered very correctly. But the acknowledged defects of expense and great complicity, and also the continual attention required to keep it in working order, have caused its gradual fall into disuse; for it was found as soon as the oil in the works, which are not in these meters in contact with the water, got thick, the tumbling-weight refused to fall, and the water passed through the half-open valve without registry, and fresh oiling was found necessary every few months.

Messrs. Chadwick and Frost, in their Manchester positive meter, cut a long flat strip off one side of the upper part of the piston-rod; against this flattened portion a roller is pressed at the end of a bent lever, the square ends of the strip or slot drive the other end of the lever at right angles to the piston-rod, causing it to actuate in that line of direction a valve, which allows the water to flow alternately through the connecting link to the back of two small circular discs; its pressure at once forces each forward in turn, carrying the main valve with it, thus forming a fluid pressure valve. This arrangement is found superior to Kennedy's meter, and in fact has gained the ascendancy over all other cylinder meters we possess; but it is an expensive meter, and the number of wearing surfaces it contains prevent that durability which a high original expenditure ought to insure to customers. It will not either, without great additional outlay, stand exposure to heated water.

A French patentee specifies a long cylinder, containing two pistons joined by a rod, passing through a central division with bearings, on which the cylinder rocks by the greater weight of fluid alternately in each end, the central bearing being hollow and arranged on the four-way cock principle, and opened and closed by the tilting of the cylinder.

A large number of meters have also been devised, with two or more cylinders as measuring vessels; these are fixed side by side, fitted with pistons, and their rods working a common shaft by means of cranks. By the revolution of this shaft two eccentrics or cams are made to open and close the valves; these are sometimes placed between the cylinders, sometimes on the outside, and in one case, in a meter designed by Mr. Duncan, placed at a considerable angle to the piston-rod. When the cylinders are placed in the same line, end to end, as is the case in some meters, the rod connecting the two pistons, by means of a long catch, is made to actuate bars placed parallel to the piston-rod and outside the cylinders. These bars move secondary valves, the primary valves being placed at right angles across the further ends of the cylinders, and driven by water pressure regulated by the secondary valves, thus forming a similar, but more clumsy, fluid pressure valve to that used by Messrs. Chadwick and Frost. In some cases the cylinders are made so as to slide telescopically on one common cylinder open at each end, with a central water-tight division; but in this arrangement the valves are a great difficulty, and the accurate fitting of the cylinders is expensive.

When the cylinders are set at an angle to one another, it is generally, as in an invention of Mr. Jopling's, at right angles, and the piston rod of one is made by direct action to open and close the valves of the other, the pair being closed in a water-tight casing.

An invention by Mr. Worthington, of the United States, consists in an arrangement of two cylinders, each containing two plungers or pistons connected by a single rod, bearing a central division plate. The valves are placed between the containing cylinders, and the alternate spaces are connected by crossway passages,from one into the other of which the water flows before it leaves the meter.

The chief object aimed at by the combination of several cylinders is a continuous discharge from the meter, and the prevention of any concussion occurring in the pipes. This is so perfectly effected by Messrs. Chadwick's meter that any additional complication and expense, such as these machines involve, is quite needless.

Another American method uses a cork piston or ram, packed with cupped leathers ; and a Mr. Heppel furnishes a solid wooden cylinder, with an annular leather bag, and causes it to work loosely in a cylindrical casing. These have their advantages in cheapness and absence of friction, but their adaptability in continual contact with water is very questionable. The best form of piston for a water meter appears to be a cylinder of metal with a flange at each end, the intervening space being long enough to allow the travel of a rolling ring of india-rubber up and down during each stroke of the piston.

There is yet another combination of pistons and cylinders, which has been devised for measuring water. The inventor places a number of cylinders round a central shaft free to revolve, and attaches the heads of their piston rods to the corners of an inclined plate centred on the central shaft ; the pressure of the water against their pistons causes them to rotate, and their revolutions open and close their respective valves. They may also be placed along a common trough or pipe, and their piston-rods in gear with a common crank shaft. They are free to oscillate, and, in doing so, valves at their junction with the main pipe are alternately open to each side of a central partition in it, which divides outlet from inlet.

The next description of positive meters includes all which are constructed to work with flexible or elastic diaphragms. The principle of these meters is, that a perfectly water-tight partition shall be formed, capable of assimilating itself to either end of a containing chamber, its edges being firmly bedded in the sides of the chamber, so that water admitted on either side alternately will force the diaphragm tight against the other. The shape of the chambers used to inclose these diaphragms is generally that of a double sector, or a sphere, or with inclined sides and flat ends. The chambers are most usually broad and shallow, and made of two shaped plates bolted firmly together, with the diaphragm between them. This is made of leather or vulcanized india-rubber, toughened by layers of calico or prepared cloth. It is generally strengthened by a central plate of metal, to which a piston-rod is attached, which passes out of the chamber and actuates the valves.

In one patented by Mr. Ramsbottom, in 1855, there are two diaphragms in doubly conical chambers, the rods of which turn a common crank shaft. On this are two mitre wheels, which turn a rotary valve between them.

In a German meter, the rod actuates a lever with a chordal rack attached to the further end. This gears with a pinion, a crank on whose shaft moves the valves.

In another meter, four diaphragms are used at right angles, and all driving the same central shaft by means of cranks. From this shaft the registry is taken, and it is made to distribute through valves the supply of water to each pair in turn.

Meters of these descriptions will work with great accuracy whilst the diaphragm remains entire. But it has been found impossible to discover any material which will endure active work with certainty, and as soon as the smallest flaw occurs, water passes without registry.

Closely allied to meters of this description are those whose measuring chambers are made of compressible bags or cylinders. One of the simpler forms of these was patented in 1850. It consists of a water-tight chamber, containing two compressible cylinders, distended with metal rings at intervals. Their upper ends rise and fall vertically, as they fill and empty, raising and lowering each end of a bar with them. Chains from these ends pass over separate pulleys, and are attached to the ends of a cross handle of a four-way cock. Another design fastens two such cylinders end to end on a rocking arm passing right through them. They rise and fall as they alternately increase and lose weight, and alter valves seated at their point of connection.

Compressible tubes have also been often suggested as water meters ; for use as such they are wrapped round a centre cylindrical core, or coiled in a ring on a circular plate, and a pair or more of rollers, revolving round a shaft placed in the centre of the bag, and pressing tight against it, are caused to move by the pressure of the water entering one end of the bag, and forcing the rollers before it, in order to escape at the other extremity. By the time one roller has arrived at the end of the bag a second comes into play ; thus a series of waves of equal and known amount are continually passing through the bag and being registered by the central shaft. An invention of Mr. Siemens' makes use of a similar principle, by causing waves of liquid to pass down a tube of rectangular section, between the sides and a flexible central division. To all such meters the same objection holds as in the case of the diaphragm meter—that they are most uncertain in duration, especially if liable to stand idle, and their flexible portions to get dry and hard.

An entirely different description of meter are those which work on the principle of rotary force pumps or fans. They are usually made with cylinders or axes revolving either in the same centre or eccentrically in outer cylindrical casings with closed ends. The simplest form is that of a plate sliding in a hollow cylindrical shaft or an elliptical disc, sliding on a crank and revolving in an epicycloidal chamber, the inlet on one side, the outlet on the other. The fluid continues to flow, and the ends of the plate or disc cut off equal quantities of fluid, and register the number of revolutions. Or, the centre cylinder may be concentric with the outer casing, and have one or more flat vanes of metal let into slots in its periphery, which are forced into it at a certain part of its revolution, between the inlet and outlet holes, by a bulge or indent in the outer shell, causing the periphery of the inner cylinder to revolve in close contact with it, and forcing out the water included between any two of the vanes. These vanes are carefully packed, and must revolve in close contact with the outer circle; and for the purpose of always keeping them tight against this, a cam is placed inside the inner hollow cylinder, which forces them out at all parts sufficiently.

A French invention proposes to shut up air in the inner cylinder, and trusts to its compression and expansion to keep them in contact.

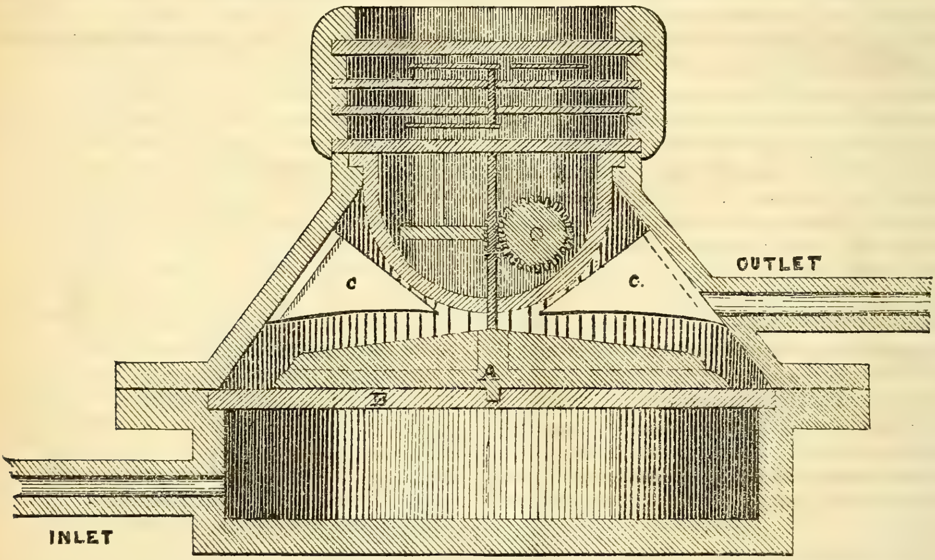
According to another, an eccentric axle is fixed inside the inner cylinder with four short arms; on to these are hinged the travelling vanes, which at a certain part of the revolution were required, bend at the hinges and recede, and afterwards again straighten and are forced forwards.

In these machines the accurate fitting and easy travel of the vanes is of great importance; but however carefully this may be carried out originally, from constant use these machines soon give signs of wearing and neglect to register accurately.

Some inventors make use of oscillating vanes or pistons swinging round in hollow cylinders from one side to the other of a fixed partition, the inlet and outlet being on each side and reversible by valves; and even more complicated arrangements of two or more swinging vanes, sometimes in adjoining cylinders, and other equally impracticable machines have been proposed.

A great many adopt the method of hinged vanes or floats, capable of laying close alongside their centre spindle, and of spreading out against the encasing cylinder under pressure of water. After the principle of the fan, the vanes are made concave against the pressure of the water, and are hinged on to a cylinder, so made to revolve eccentrically, that just before it reaches the inlet opening the blades are folded closely down, but on passing it they spread, and do not again close until they have passed the outlet.

Different arrangements of two cogged wheels, rolling in contact, have also been suggested; they are made of considerable breadth, and are placed in a double cylindrical casing, the one riding loose, the other fixed on a shaft which actuates the register. The teeth of such wheels must be very carefully made, in order to continue in contact at every instant of their revolution, the water being usually supplied immediately under the point of contact. It will be easily understood that the efficiency of the machine depends en-



tirely on the good fitting of the gearing surfaces of the wheels, and which equally applies to the preceding description of meters, to the careful packing at each end of the drums. A meter which has not come into public use, but which has been found to work satisfactorily when applied to measure the water supplied to steam boilers, consists of a string of balls, fitting accurately in a loop formed in the supplying-pipe, and, passing over a pulley at each end, the water enters on one side of one pulley, and, carrying the string of balls before it, passes out at the other extremity. These balls cause the pulleys to revolve, and show how much water has passed.

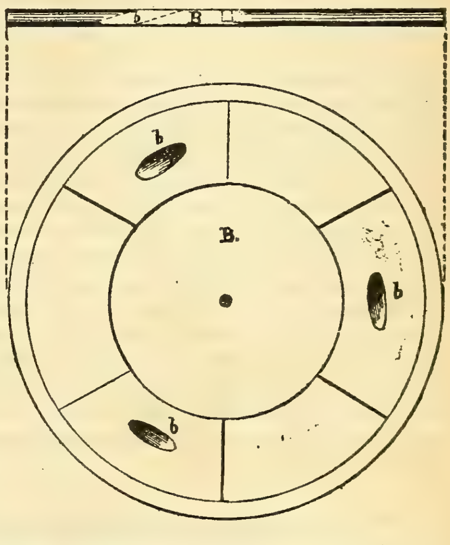
Amongst inferential meters, which depend for their accuracy on their estimate of the velocity of the water passing through them, those which register the revolutions of an annular ring of metal, fitted with floats or paddles round its periphery, are most numerous; the water in this case being admitted through apertures as nearly as possible at right angles to the surface of the floats, impinges against them and causes revolution, but in a very irregular proportion to the speed and pressure of the water. An invention of Mr. Ramsbottom's has been used to some extent, and consists of a wheel with radial floats. Another machine, by Mr. Taylor, is very similar. He uses a horizontal wheel, provided round the periphery with radial floats, and riding on a vertical spindle in a closed chamber. It is to be made of any material of the same specific gravity as water, in order to reduce friction on the bearings, and is driven by the water admitted through small holes close to the wheel. This meter has been used considerably in the north of England, but is found much inferior in correctness and power of discharge to others.

To insure an even flow, which was the only condition under which these meters would work accurately, and to prevent low-pressure water from passing at all, several different methods have been devised.

By one arrangement the water is required to raise a clack-valve, held down to its seat by a delicate spring before it can impinge against the drum ; by another, the water is caused to pass through a contracted elastic orifice ; and by a third means, the flow of water in its action on the drum is regulated by a specially designed governor.

The next class of inference meters include all those which register the rotations of drums with screw blades fixed round them. These drums are fitted into long cylindrical casings, and the water flows past them, having first been directed through fixed guides turning in the opposite direction, and causing it to impinge on the drum-blades at nearly right angles. An earlier invention of Mr. Siemens' is of this description, who uses two drums, or two pairs of drums, turning in opposite directions, and set end to end in the same tube. The drums are made hollow, of a peculiar alloy, and have eight perfect screw threads passed round each. The registration is taken off the central ends of the drum-shaft by means of mitre wheels, and there are directing guides equal in number, but exactly opposite in direction, between each.

A patentee of 1851 places a similar drum, but rather longer, on a valve seating in a vertical pipe; it is thus rendered capable of lifting before any impurity which may be carried along with the



water. Some others use a great many series of drums and guides, and occasionally choose to admit the water without guides, simply between two reversed drums on the same spindle. The accuracy of these machines depends largely on the careful fitting and balancing of the drums, and their continuing to work without friction; but even under the most favorable circumstances they will not register with sufficient correctness at varying pressures, the error generally tending towards insufficiency at low pressure, and rising above the real amount at moderately high ones.

A further improvement has been suggested and used by Mr. Siemens and others, on the principle of a Barker's mill, whereby the water is admitted into the interior of a chamber fixed on a spindle, out of which it flows by means of bent or curved hollow arms; the reaction of the outflowing liquid (for the vessel is entirely under water) causes it to rotate in an opposite direction; the spindle moves on a steel pivot encased in a water-tight oil-chamber; the water is admitted through a dirt-box; the revolving chamber is furnished with retarding vanes, and the upper end of the shaft has a worm-wheel attached which works the register.

The above meter has found most favor before the public, both in England and abroad, of all the meters yet introduced; but, notwithstanding its superiority, it possesses many defects. It is expensive, and is not by any means certainly correct under all pressures; it is, besides, so very delicate that it continually requires inspection and repair. It will pass water through at low pressures with a very insufficient registry, and will work backwards without difficulty.

A great step in the removal of all the above defects, both in this and every other meter yet introduced, is exemplified in an invention by Messrs. Cook and Watson—a meter which has only lately come before the public notice. It consists of an upper plate, A, indented on the under side, with a ring of thumb-holes, and riding loosely in a chamber over a lower plate, B, through which inclined inlet holes, *b*, *b*, are bored. The water rises through these holes, raises the upper disc, and acting against the square ends of the thumb-holes, causes it to rotate at the same time. This action of course requires some small power to commence, but as soon as the upper plate is lifted, it must also necessarily rotate. When the supply ceases, the upper plate falls, and forms a tight valve against the return of the water; and since during its period of revolution this plate floats in a film of incoming water, there are no wearing surfaces involved in the machine. Small arms or wings *a*, *a*, are placed on the upper surface of the revolving plate A, and also *c*, *c*, in order to produce regularity of motion under varying pressures, and appear, from the specimens I have at different times been able to test, to do so with complete success.

These machines are not expensive, and offer but small opposition to the flow of the liquid, and certainly appear to be *the simplest and most practicable form of high-pressure meter yet invented.*

A very different description of inferential meter consists in the use of a rod of alabaster, or other slowly soluble material, encased in a glass rod graduated, and at its lower end in contact with the running water. It is kept pressed down, and as it dissolves, the top descends and is supposed to denote the quantity of water which has passed. This seems very simple, but the readings must often be liable to considerable variation.

ON THE DENSITY OF WATER IN MARINE BOILERS.

Written for "Van Nostrand's Magazine."

The water used in a marine boiler usually contains a quantity of saline substances, the most deleterious of which is sulphate of lime ; this is principally deposited on the heating surfaces of the boiler, when the water in the boiler can hold no more of it in solution.

The point of saturation varies considerably, decreasing as the temperature is increased, and increasing as the temperature of the water decreases ; and as the temperature of saturated steam and the water from which it is generated, when they are in contact, are the same, the capacity of the water in a steam boiler for holding in solution the sulphate of lime in sea water, decreases as the temperature of the steam is increased ; but as the pressure varies with the temperature—one increasing when the other does, though not in the same ratio the point of saturation of the water in a steam boiler decreases (holds less sulphate of lime or saline matter in solution) as the pressure of the steam in contact with the water is increased.

The pressure of steam in marine boilers has been increased within the past few years by the introduction of compound engines, using steam expanded tenfold, and even more, and economy in this kind of engine can only be obtained by the use of steam of a high initial pressure, cutting off the admission to the cylinder at an early part of the stroke.

In this, as well as in the modern single cylinder engines, the surface condenser has been, and is still used to condense the steam after it has done its work in the cylinder, keeping the condensed steam apart from the condensing water, thereby making it possible to furnish the boiler with fresh, or partially fresh water, instead of the jet condenser, which furnishes feed water but very little less dense than the sea water.

It is well known that there is more power required to work the necessary pumps of a surface than those of a jet condenser, each condensing equal weights of steam; this is a constant loss whenever the engines are used, and would amount in time to many horses power; but in addition to this constant expenditure there is the difference in first cost between jet and surface condensers, besides the increased weight and wear of the latter over the former.

These are some of the disadvantages of surface condensers, and if they have so many, why use them? Simply, because we desire to have fresh water to feed to the boilers, and thus prevent this deposit of sulphate of lime, which has only about $\frac{1}{30}$th* of the conductivity of iron, and by this decreased conductivity, decreases the efficiency of the heating surface of the boiler.

The density of the water in a boiler is measured by a hydrometer, and when used to measure the density of salt water is usually called a salinometer; with it we do not measure the amount of sulphate of lime in the water, but the total amount of saline matter held in solution, the greater part of which is common salt.

Sea water contains about 3 per cent. of this saline matter, or 1 lb. in 32 of fresh water, and the hydrometer is graduated in 30 secs.; one being the density of sea water, and two twice that density, the marks on the stem of this hydrometer, if the stem be of a uniform diameter, are nearer each other between three and four, than between zero and one; this is accounted for by the increased density of the water, and consequently its increased buoyant power.

To illustrate this, take any body weighing 62.5 lbs., and 1 cubic ft. in volume; this will be equal in weight to a cubic ft. of fresh water, and will displace a cubic foot of water, and the body will be submerged; call this the zero point, increase the density or weight of the water from 62.5 lbs. to 64.5 lbs. per cubic ft.; then will the body rise out of the water and be but partly submerged, though it still weighs 62.5 lbs., and still displaces 62.5 lbs. of water. Now, if the body be wholly submerged it will displace 64.5 lbs. of water; but displacing but 62.5 lbs., which is equal to the weight of the body, it is but $\frac{625}{645}$ immersed; now, if the density or weight of the water be increased 2 lbs. at each trial, a cubic foot will weigh 66.5, 58.5, 70.5, etc., respectively; and the body will be immersed in the first case, in fresh water $\frac{625}{625}$ or unity; in the second $\frac{625}{645}$; in the third $\frac{625}{665}$; in the fourth $\frac{625}{685}$; and in the fifth $\frac{625}{705}$; it is evident that the difference between $\frac{625}{625}$ or unity and $\frac{625}{645}$, is greater than between $\frac{625}{685}$ and $\frac{625}{705}$; this will account for the difference in the length of spaces on a hydrometer.

The usual practice of engineers is to carry the density of the water in the boilers at from 1 and $1\frac{1}{2}$ to $\frac{2}{30}$ secs., varying with the steam pressure, reducing the density as the pressure is increased; and to maintain a low degree of density of the water in the boiler, we must blow off a great amount of water, which has already absorbed enough of heat to raise it from the lower temperature of the feed water to the higher temperature due to the boiling point of the water under the pressure and density maintained.

The question naturally arises: at what temperature or pressure is all of this non-conducting substance, sulphate of lime, deposited, or at what density of the water? and are we blowing off from the boiler, water that is increased in density by salt or sulphate of lime? If there is no sulphate of lime in the water blown off, why not maintain the density of the water nearly up to the point of saturation with salt? If no more deposit of sulphate of lime will take place, surely there will be a saving of fuel.

In view of the unsettled point, as to what is the most economic density of water to maintain; and whether main-

* Some writers give it as much as one-sixteenth, and others as low as one-thirty-seventh.

taining high pressure steam in marine boilers (say from 60 to 80 pounds per sq. in.) occasions a greatly increased deposit of sulphate of lime, I would suggest that a series of careful experiments be made to determine the density that is most economical to maintain under different pressures of steam, making a chemical analysis of the water before entering the boiler, and of that blown off, determining the weight, thickness and quantity of scale deposited in each trial under different pressures and densities, in each trial evaporating the same weight of water, which should be determined by surface condensation in a continuous pipe.

The able paper of M. Cousté, "Annales des Mines," 1854, would be of much interest to any one making experiments on the incrustation of marine boilers, a subject which is of so much pecuniary interest to steamship owners throughout the world.

The following formula for determining the loss per cent. by blowing off was originated and much used by the writer some years ago, and has been found much simpler to explain than those generally given in the books, especially to a student.

The quantity of water entering the boiler is taken at unity; the quantity of water blown off, a fraction of unity, having for its numerator the density of the feed water in 30 secs., and for its denominator the density of the water in the boiler in 30 secs., unity minus the fraction representing the quantity of water blown off equals the quantity of water evaporated; multiply the difference in temperature between the feed water and the water blown off, which is also the temperature of the steam in contact with it, by the fraction representing the amount of water blown off; this will equal the quantity of heat lost or blown off; then multiply the difference between the temperature of the feed water and the total heat of the steam by the fractional part of the water evaporated; the product will equal the quantity of heat given to the water evaporated or the heat utilized; the sum of the heat utilized and the heat lost equals the total heat required of the fuel; then, as the total heat required of the fuel is to the heat lost, so is 100 per cent. to the loss in per cent.

This does not take into consideration the higher temperature of the boiling point of water by increased density, which is about 1.2 degrees for each 30 secs. per hydrometer.

Let d = density of feed water in thirty seconds.
D = " water in the boiler in thirty seconds.
t = temperature of feed water in deg. Fahr.
T = temperature of steam in deg. Fahr.
$1114 + .305\,T = H$ = total heat of steam in deg. Fahr.

$\frac{d}{D}$ = quantity of water blown off when the amount fed in is unity.

$1 - \frac{d}{D}$ = quantity of water evaporated when the amount fed in is unity.

$$\frac{100\left[(T-t)\frac{d}{D}\right]}{\left[(H-t)\left(1-\frac{d}{D}\right)\right]+(T-t)\frac{d}{D}} = \text{loss in per cent.}$$

J. C. K.

A most useful work at Chatham Dockyard has now been completed—a tramway extending to most parts of the dockyard. It unites the various building slips, docks, factories, storehouses, etc., and also joins the Dockyard Extension on St. Mary's Island. As there are now very massive materials to move through the yard, this tramway will prove very useful. There are as yet no factories or storehouses on the Extension works, and the tramway will be found of great advantage in conveying materials, stores, etc., from the old dockyard to the new one, when ships are being repaired there. The tramway was formally opened on Wednesday by Captain W. C. Chamberlain, the Captain-Superintendent, who was accompanied by the chief officers of the yard. The party was conveyed in trucks over the various sections of the tramway, drawn by one of the loccomotives that is to be used on the line.—*Mechanics' Magazine.*

A method of imparting a yellowish hue to white marble is sometimes wanted. Dr. R. Weber has made known the fact that alcoholic solutions of perchloride of iron are not precipitated by carbonate of lime, and may therefore be applied in different degrees of concentration to impart a more or less deep yellow hue to white marble. The converse of this—the removal of yellow stains from white marble—is still a desideratum.

NOTES ON FIRE-PROOF FLOORS.*

The subject of fire-proof flooring can scarcely be treated under one head. For a floor might be, practically, fire-proof in a position where the heat is not likely to be great, whereas it would be useless otherwise. In the ordinary range of dwelling houses there is nothing to burn but the furniture and the timbers of the floors and partitions, mostly protected in part by plastering, and the heat given out is seldom enough to consume entirely even them. But in a warehouse stored with goods, which add to the mass to be consumed, the power of fire is shown in its most terrible form, and strong iron doors are crumpled up like paper. In a private house also, not only is there the advantage of there being less heat, but the floor-timbers usually bear at each end on a wall or partition. And even if the latter be of wood, it can easily be made almost fire-proof, either by filling in between the timbers, after the French manner, or with brick nogging and good plastering. But both must be carried up the whole extent of the partition, without vacancies between the floors.

By the modern plan of keeping the wall-plates out of the wall, the solid bearing is lost, and the wall-plate itself more exposed. The custom of carrying this plate upon stone or iron corbels is a bad one as respects fire; for, though neither iron nor stone will burn, it will be shivered to pieces under the action of fire. A safe bearing can easily be obtained by forming oversailing courses of brickwork. No fire that I have ever known will destroy that.

In an ordinary dwelling-house, with plastered walls and no unusual amount of furniture, I look upon the plan of using wrought iron joists filled in with pugging, as being a good protection, provided always that the under sides of the joists are well protected by plaster. I consider, however, that a very thick layer of an ordinary pugging, filled in between wooden joists, would form as good a defence against fire, provided that the pugging could be combined in some way with the plastering of the ceiling, so as to form the two into one mass. The difficulty as to this, and it is one which I have not been able to get over, is that the fillets on which the pugging rests must be tolerably wide, and be kept some distance up the joists in order to prevent the latter splitting with the nails used for the fillets. Thus there is a space left between the sound boarding and ceiling too great to be filled in by the key of the plastering. This can be got over with iron joists, as the sound boarding can lay on their lower flanges. In case these joists are not used, I think that the best plan is to use pugging, say 3 in. thick; to have the sound boarding in very narrow widths placed half an inch apart so as to let the pugging pass through the interstices, and then to render the under side of the sound boarding whilst the pugging is wet. But the boarding must, of course, be thoroughly dried, or as bad an enemy may be admitted almost as fire—namely, dry rot.

Before leaving the subject of dwelling-house floors, I must, however, call to your mind that the slight joists now used present very much greater facilities for destruction by fire than did the old heavy timbers formerly used. As architect to one of the chief insurance offices, and also to the London Fire Brigade, I have seen several thousand cases of fire, and it has been very rare, indeed, in the case of a dwelling-house, that a solid piece of timber has been burnt in more than an inch or so. A girder would be safe. But such an injury to one of our light joists would be fatal.

A few words may, perhaps, be devoted to staircases, though I am not sure that they come quite within the scope of my subject. But they are incalculably the most important part of the house as respects the means of escape, whilst they are, unfortunately, just the very part up which the flames rush with the greatest violence. In several damaged houses that I have seen, many of the rooms were scarcely burnt at all (the doors having been closed), whilst the staircase was utterly destroyed. It happens too, unfortunately, that this part of the building is, in our modern system of construction, the least protected. The wooden staircase is made with a thin-cut string, allowing full play for the flames against the end of the treads. The fire thus gets

* A paper read by Professor Lewis before the General Conference of Architects, 1871.

easily between the tread and the plaster soffit, and the utter destruction of the staircase is effected in a few minutes. Doubtless stone staircases are better than wooden ones; but I have seen even them repeatedly destroyed by being split by the heat and water, as in the case of a large house at the West-end, in which three people were suffocated. The stairs were of stone, and, very curiously, the landings were formed of ordinary wooden joists, with a thick ceiling of plaster. Every step, although of good solid Portland stone, was broken to bits. The wooden landings were absolutely uninjured. For safety, we must go back again to the old plan (for we are not quite so much wiser than our fathers as some think) and use thick close strings (protecting the sides of the treads), whilst the space between the latter and the soffit is filled with plaster.

The real difficulties of fire-proof construction begin where there is a large mass of combustible materials as in warehouses and similar structures. In these, the heat developed is something which an ordinary observer would scarcely credit. I exhibit some specimens of brass and iron nearly in a melted state, showing that the temperature which they had failed to withstand must have been some 2,000 deg. Fahrenheit. The whole place, in fact, must have been a glowing furnace. Now, to resist this heat, the use of timber is generally scouted as absurd, and reliance placed upon iron. This material no doubt will not burn; but from the specimens shown, you see that it will melt. Long before its melting point, the heated iron must have softened and lost its strength; and long before it began to soften it would snap asunder when chilled by the water dashed against it by the firemen. It is the latter risk that makes the iron construction so dangerous, and the boldest man in the brigade would hesitate to enter a building on fire whose supports he knew to be of iron. This risk is mainly owing to the exposure of the iron to the direct action of the flames, and it is curious that, almost without exception, what is called "fire-proof flooring" allows of this action. If that be the case, I know of nothing whatever that can save the floor.

In one of the warehouses burnt in the great fire in Tooley street, a different plan of iron fire-proofing had been tried on nearly every story. But each left the under side of the iron exposed. The result was a scene of utter destruction very difficult to realize. For the wreck is much greater where iron is used than where timber is employed. The iron expands and strains the walls; whilst wooden girders would leave them intact. I remember one striking instance of a factory which was very strongly built on a circular plan, the iron floor-girders radiating from a large well-hole in the centre. These girders of course expanded when the place was well on fire, twisted and broke the iron curb, and then pushed the walls bodily out. There must always be a likely chance of this occurring if any part of the iron be exposed. In such a case, and I say it distinctly, it will be safer to use thick wooden girders and brick arches than to turn these arches upon iron. It is not often that one has the opportunity of comparing the two materials, but I was enabled to do so in a large warehouse on Tower-hill. All the iron girders, though of sufficient strength, except in the case of fire, snapped in half. The wooden girder was burnt in for about an inch, but was otherwise intact.

It is difficult so to cover iron as to protect it, and many schemes have been devised for protecting it otherwise. The favorite one, no doubt, is to make the girders and columns hollow and fill them with water. This looks well in theory. But the ironwork must be *always* kept filled or it never will be so, when wanted; and there is then a very unpleasant risk of leakage. But setting that aside, if the hollow work be open to the air the water will soon be blown off into steam by the terrific heat generally attained; and if closed, the whole of the ironwork will soon assume the conditions of a steam boiler with its safety valves screwed down. I scarcely need quote examples to prove this. I have one, however, ready. At a large coal store on the Regent's Canal basin, the pipes of the hydraulic apparatus were full and closed. The cast-iron head, $1\frac{1}{4}$ in. thick, was split open from end to end and the pipe torn bodily out of it. All other attempts to protect iron efficiently have failed, as far as I know.

Iron may sometimes be made useful in a minor way. I once saw at Nottingham, where much good work is done with Dennett's concrete, the ceilings of a factory formed of sheet iron. This is useless against a body of flame from below, but it prevents sparks dropping down from above. And as the floors are saturated with oil, this precaution has, to my knowledge, been of much value. But this is an isolated case, and I confess that as a general rule I see no way of using iron anywhere with success, unless every part is protected from the action of the flames. In fact, the result really seems to me to be that the only secure protection from fire is a structure of brick arches on brick supports. Nothing else that I can call to mind will stand the effects of great heat and the action of flames ; stone and granite fly to pieces, but good brickwork never does. Perhaps the strongest case of endurance against fire known of late years was that at Tooley street, where an immense range of cellars was filled with oil, which ignited. For weeks this oil was burning—a rolling sea of fire. The cellars were vaulted with brick. They had this glowing mass below and the heated *debris* above, and yet after a careful scrutiny, when the oil was got out, I could detect scarcely a trace of injury. If this mode of construction cannot be used, I would trust strong wooden timbers thickly pugged and supported on strong wooden posts, in preference to iron girders on iron columns. But I cannot repeat too strongly, that, with a large mass of fire, no construction, under any circumstances, could be considered as really fire-proof, except solid arches on brick supports.

OBSERVATIONS UPON MAGNETIC STORMS IN HIGHER LATITUDES.

From "Nature."

The extension of the telegraph into the more northern latitude of the Shetland Islands, between 59 deg. 51 min. and 60 deg. 51 min. 30 sec. N., has afforded a much better opportunity of observing the frequency and variation of the magnetic and auroral storms that have of late excited some attention and discussion in these pages.

Some of the earliest recorded observations upon the strength and direction of these atmospheric storms, date from the time when the extension of the telegraphic wires over England rendered the phenomenon visible by the disturbance of the magnetic needle placed in circuit with the wires, and to a certain extent rendered possible the mapping down of the position and direction of the magnetic storm over certain tracts of Great Britain.

On the 24th September, 1847, remarkable magnetic disturbances were observed in London, and the direction and deflection of the magnetic needle noted. The effects of this magnetic storm were carefully observed at Dawlish, Norwich, Derby, Birmingham, Rugby, Cambridge, Tonbridge, Wakefield, Edinburgh, and York. The magnetic disturbance appears to have commenced about 1 h. 5 min. P. M. on the24th, and continued with variable intensity until 7 h. 30 min. A. M. on the 25th.

It may be interesting to give some of the galvanometer readings recorded as indicating the rapid oscillation and deflection of the galvanometer needle. In the period of time between 4 h. 17 min. P. M., and 5 h. 48 min. P. M. on the 24th, or in about one hour and a half, the direction of the current had changed no less than 10 times, showing a maximum swing of the needle over an arc of 50 deg.

H. M. S.	Deg.	H. M.	Deg.
4.17	15 left	5.5	15 left.
4.20	20 right	5.11	12 "
4.25	1 "	5.16	10 right,
4.25.30	18 "	5 22	18 left.
4.35	6 "	5.25	14 right.
4.38	12 "	5.28	13 left.
4.45	20 "	5.32	20 "
4.50	10 left	5 34	26 "
4 51	17 "	5.42	29 "
4.55	0 "	5.48	30 "
4 56	8 right		

During this magnetic storm, the variation of the dipping needle, which was observed in London every 30 min., ranged from 69 deg. 30 min. to 67 deg. 50 min.

In some cases these magnetic storms were so severe as to impede the working of the railway signals. On the 18th of October, 1841, a very intense magnetic disturbance was recorded, and amongst other curious facts mentioned is that of the detention of the 10.5 P. M. express train at Exeter 16 min., as, from the magnetic disturbance affecting the needles so powerfully, it was impossible to ascertain if the line was clear at Starcross. The superintendent at Exeter reported the next morning that some one was playing tricks with the instruments, and would not let them work.

It will be fresh in the memory of many of our readers that during the month of October, 1870, very remarkable and brilliant "auroræ" were observed in London, chiefly of a deep blood red color, spreading from the zenith over a great portion of the heavens.

It is, however, in the more northern latitude of the Orkney and Shetland Islands that the grandeur of these wonderful electrical phenomena can be observed, and that reliable data can be obtained from which hereafter some practical result may be deduced.

As observed in Orkney and Shetland, the aurora, as a general rule, appears to concentrate and emerge from behind a dense mass of dark cloud lying low down in the horizon towards the north. The edge of this cloud-bank is serrated and jagged, as if the mass were electrically in a high state of tension. From behind this cloud-bank "dark" streamers will appear to start up high into the zenith, appearing as if attenuated portions of the edge of the cloud-bank had been dragged by some invisible power, these dark auroral rays being at the same time transparent as regards the power of transmitting the light of the stars, which shone through with undiminished splendor. At the same moment that these dark rays are emicant, brilliant green, violet, crimson, and white rays appear to stream upwards towards the zenith, but always with a less persistence of duration. These colored scintillations change with greater rapidity than the black rays.

During the month of December, 1870, some very vivid prismatic tints were observed from the Island of Eday. From careful observation it was then remarked that the red colored rays appeared generally to be of a partially opaque nature, and it could be readily seen that the light of a star, when viewed through the red scintillation, was dimmed as compared with the brilliancy of the same star when observed through the scintillations of another color.

In some of these displays, the most vivid and varied coloring was exhibited. These were noted down as visible to the eye at the same time, and as the colors were observed in contrast, the distinctiveness and brilliancy of the tint became the more decided. Black, pale yellow, strong yellow, white, violet, pale blue, bright green, crimson shade fading into a reddish pink, pale orange, and a delicate sea-green tint. So far nothing approaching to the indigo hue has been noticed. With this exception, the entire prismatic colors and blending tints may be said to have been perfectly developed in the rapid electrical scintillations of the aurora. The colors fade away and change with astonishing rapidity, and this variation in tint will take place without apparently any great electrical disturbance in the special ray observed, beyond a slight flickering motion. In these regions, where the atmosphere is so perfectly still and at times calm, repeated observation has determined the existence of very appreciable sound to the ear, as an accompanying phenomenon to the rapid rush of the auroral streams towards the zenith. The intensity of the sound emitted varies considerably. At times, it greatly resembles that of the rushing noise caused by the firing of a rocket into the air when reaching the ear from a distance. At other times it has a strong resemblance to the sound produced by the crackling of burning embers, but wanting in any very distinctive sharpness.

In all these cases of auroral displays the inductive effects upon the telegraph wires are very strongly marked; currents of varying intensity and direction flowing unceasingly through these metallic circuits.

The result of observations made in Shetland during the months of September, October, November, and December, 1870, tend to show that these auroral disturbances attained their maximum effect upon the wires between 8 h. 30 min. and 9 h. 30 min. A. M., and between 8 h. 30 min. and 10 h. 30 min. P. M.; and such is the unstableness of these induced auroral currents, that frequently in 5 min. the electromotive force will vary from very much less than that of a Daniell cell to a current of such intensity that a brilliant stream of light will flash across the points of the lightning conductors with sharp detonating reports, the electromotive force of which would be scarcely equalled by 500 Daniell cells.

In January, 1870, very curious electrical phenomena were observed at Lerwick through the day-time, in connection with the N. E. gales so prevalent at that period of the year. In Shetland these gales are almost without exception accompanied with very severe hail-storms. The day begins bright and fine, a clear sky, the barometer rapidly rising; low on the horizon may be observed dense and angry-looking clouds. One by one these clouds travel fast towards the zenith, when all at once a fearful gust of wind, accompanied with the most violent hail-storm, will apparently break out of the cloud, and continue for about 15 min. The wind then subsides, and the day appears as fine as before. In half an hour's time a second cloud will have appeared, and there will be a repetition of the temporary tornado and hail-storm. The remarkable circumstance attending these successive storm clouds is that they appear to be a purely electrical phenomenon. The moment that the icy discharge takes place from the cloud with its accompanying "crack" of wind, an induced electrical current appears upon the wire, so strong that it attracts firmly down the armatures of the telegraph Morse apparatus. The moment, however, that the hail ceases, the current passes off, but with this result, that each successive cloud storm appears to induce a current flowing in an opposite direction from the last, that is to say, the currents appear to be (using conventional language) positive and negative in their effects.

That these storms are "electrically excited" there is no disputing, and that they occur during the prevalence of the chief auroral displays is also a matter of observation; but so far their connection with aurora has not been sufficiently determined to permit any opinion to be expressed.

The recent successful completion of the telegraph circuit to Shetland, and the extensions immediately to be carried out 100 miles farther north, will afford much greater facilities for auroral observation than has hitherto existed. It is also proposed to institute a careful spectroscopical examination of the colored scintillations; and now that the Meteorological Society are about to establish an observation station in Shetland, there is every prospect of some valuable data being collected on this interesting subject, which may hereafter guide our meteorological students in arriving at some satisfactory conclusion regarding the laws of electrical storms and auroral induction. At present we are only able to record a few carefully observed facts.

THE FAIRLIE SYSTEM.

From "Engineering."

On a recent occasion we stated that the experiences obtained with the Fairlie engines on the Festiniog Railway, were only such as served to show on a small scale that which might be expected from the system when it received its full measure of development, and was enlarged from the minute 2 ft. gauge of the little mineral line, to the greater requirements of a heavy and general traffic on a broad gauge railway. At the same time we pointed out, that while to Mr. Spooner, engineer of the Festiniog Railway, was due all credit for the energetic and untiring manner in which he had always assisted in the development of the Fairlie system by affording to it the full use of his line, still the time would soon arrive when a larger and more important railway must become the testing place of the double bogie engine.

The recent experiments in Russia have fully confirmed this opinion, and although St. Petersburg is not so accessible as Port Madoc, it is to the former place that all interested in ascertaining the real capabilities on a large scale of these engines should for the present address themselves. Fortunately the performances are so minutely recorded, and are authenticated by such unquestionable authority, in the official reports, that the long sustained and persevering efforts to throw doubt and discredit on the system during its earlier stages on the Festiniog Railway, may well be spared now that it has arrived at more mature growth. Possibly this may not be the case, for it is only a few weeks since, even while the recent experiments were proceeding with the utmost success, that an unfounded rumor was circulated that the Fairlie engines sent to Russia had proved failures. We say unfounded, because the only basis upon which this false report rested, was the fact, that on a recent occasion the Emperor of Russia inspected one of the engines recently sent out, and which was mismanaged for the moment by the men in charge of her.

The visit of the Imperial Commission to the Festiniog Railway led to the Fairlie engines being built for the Livny Railway, a narrow gauge line, 38 miles long, in the Government of Orel, Central Russia. The results obtained on the Livny Railway led to the adoption of the same system on the Tamboff-Saratoff Railway, a line 225 miles long, and opened in 1870. Again, the Grande Société of the St. Petersburg and Moscow Railway, desirous of satisfying themselves as to the real capabilities of the system, directed experiments to be conducted with two of the new engines, Nos. 5 and 6, which had been sent out for the Tamboff-Saratoff Railway.

The Count Bobrinski, now the energetic Minister, was, if not the first, at least an early advocate for the construction of railways in Russia. More than 34 years since, he brought about the construction of the short line from St. Petersburg to Tsarskoée-Selo, and urged the commencement of the railway from St. Petersburg to Moscow. This line, which was not completed till 1851, is a monument of autocratic engineering. Throughout its whole length of 400 miles it bears the mark of semi-barbarous extravagance. Its most remarkable feature is that it is without a curve for its whole length ; the Imperial command willed that it should be straight, and it was straight. But it has heavy gradients, and to surmount these, powerful engines, built by Cail and Débbs, have been employed, and these are only able to carry a very limited load ; to obtain engines capable of a higher duty is the object of the Grande Société working the railway, and with this view the Fairlie engines belonging to the Tamboff-Saratoff Railway were brought up to Malaia-Vishera on the Nicolai (St. Petersburg-Moscow) line, in order to test their capabilities.

The ruling gradient on this railway is 1 in 125, about 10 miles long, the remaining 390 miles having gradients not exceeding 1 in 500, and only a few short lengths with inclines of 1 in 200.

The construction of the Tamboff-Saratoff engines is similar to those working on the Livny narrow gauge railway, which were illustrated and described in "Engineering," of November 10th last. The Tamboff-Saratoff and the Nicolai Railways are built, however, on the usual Russian gauge of 5 ft., and the locomotives of which we are now speaking are heavier and considerably more powerful than those for the Livny line. Each engine is placed on 2 bogies, each bogie resting on 6 coupled wheels, 3 ft. 6 in. in diameter, and each having a pair of cylinders 15 in. in diameter with 20 in. stroke. The wheel base of each bogie is 8 ft., and the total wheel base of the engine is 29 ft. 3 in. The heating surface of the engine is 125 sq. ft. in fire-boxes, and 1,500 sq. ft. in the tubes, making a total heating surface of 1,625 sq. ft. The weight of the engine empty is 43 tons, in working order about 54 tons. The tanks are made to contain 1,800 gallons of water ; there is room on the engine for about 400 cubic ft. of wood fuel.

A couple of days before sending the engines to the part of the line where the gradient is situated, they were running about the stations, and the remarkable ease and steadiness with which these engines ran on curves, and over points and crossings, attracted much attention.

The two engines having arrived at St. Petersburg from Riga, they were dispatched to Malaia-Vishera Station, where the trials were to begin, and on December 1st a numerous party of engineers and gentlemen interested in railway matters, started with the trial train ; among these were General Kœnig, Director of the Nicolai Railway, Mr. Wall, Locomotive Superintendent of the line, and a few other engineers of the Grande Société. A commission of distinguished engineers from the Government Railway Department was also present.

The line from Malaia-Vishera to the Okoolooka station, a distance of 52 miles, begins with a rising gradient, averaging 1 in 240 for a distance of 22 miles; then comes the gradient of 1 in 125, 10 miles long, after which the road falls with an average incline of 1 in 240.

The trial train consisted of 45 4-wheeled loaded wagons, weighing 15 tons each, and 2 saloon passenger carriages, making a gross load of 705 tons, exclusive of the weight of the engine. The train started from the station with perfect ease, and at a very short distance from the station the speed attained was 13 miles an hour, which was maintained throughout except on the gradient of 1 in 125, where it was diminished to $10\frac{1}{4}$ miles an hour. About the middle of this gradient is situated a station, where the train is obliged to stop and take in water and fuel. This place is rather a trying point for an engine coupled to a heavy train, there not being any level place from which to start. Nevertheless, the Fairlie engine did its duty well, starting without the least trouble, and pulling the train to the end of the gradient without difficulty. Although the rails were in a miserable condition from the thawing snow, which had fallen all day, there was no slipping, and sand was not used at all. The engine kept her steam perfectly, the gauge marking only a difference of pressure from 130 to 140 lbs. The quantity of wood fuel consumed for the whole run of 52 miles was 502 cubic ft., and the lighting of fire and getting up steam required about 60 cubic ft. more. From the Okoolooka station the engine took back to St. Petersburg a passenger train, running on an average at the rate of 26 miles an hour, the speed being diminished in passing over the points, crossings, and bridges. In order to keep time, trains are obliged to increase speed sometimes to 30 miles an hour between the stations.

The performance we have just described is well worthy of being examined in some detail. Including the engine, the gross weight of the train was 759 tons, or 1,700,160 lbs., and on the gradient of 1 in 125 the resistance due to gravity alone would thus be $\frac{1,700,160}{125} = 13,601$ lbs.; and if we take the frictional and other resistances as averaging but 8 lbs. per ton for the whole train—a very moderate allowance—these resistances will amount to $759 \times 8 = 6,072$ lbs. The total resistances would thus be $13,601 + 6,073 = 19,673$ lbs. The average speed on the gradient is stated to have been $10\frac{1}{4}$ miles per hour, equal to 902 ft. per minute, and the effective horse power developed must thus have been:

$$\frac{19,673 \times 902}{33,000\frac{1}{4}} = 537\frac{2}{3} \text{ horse power.}$$

This is probably by far the greatest horse power ever developed by a locomotive when running at the moderate speed of $10\frac{1}{4}$ miles per hour, although at high speeds it has been exceeded. Each bogie having a pair of 15 in. cylinders, with 20 in. stroke, and the wheels being 42 in. in diameter, the pull which the engine is capable of exerting for each pound of effective pressure per sq. in. on the 4 pistons will be:

$$\frac{15^2 \times 20 \times 2}{42} = \frac{225 \times 20 \times 2}{42} = 214 \text{ lbs.};$$

and the gross pull of 19,673 lbs. must thus have required a mean effective pressure of $\frac{19,673}{214} = 91.9$ lbs. per sq. in. on the pistons. This pressure could be easily obtained with the steam pressure maintained in the boiler. A point of great interest connected with the trial was the amount of adhesion found to be available. The experiment, it must be remembered, was carried on during a snow storm, and no sand was used, yet the engine did its work steadily without slipping, while the pull was equal to $\frac{19,673 \times 100}{54 \times 2,240} = 16\frac{1}{4}$ per cent. of the load on the engine wheels.

All the persons who assisted at the trials were highly satisfied with the performance of this engine; it was in all respects a complete success, and Mr. Fairlie, who was of the party, was warmly and deservedly congratulated.

The acquirement by the Grande Société of Fairlie engines to work the gradient on which the trial was made, will be highly desirable. At the present time the goods trains are worked on this part of the Nicolai line, as we have stated, by the Cail engines, weighing 44 tons in working order, with 8 coupled wheels, giving a total weight on the rail of $5\frac{1}{2}$ tons per wheel, which occasions a great wear to the permanent way.

It is impossible to make a correct comparison of the consumption of the fuel between the 8-wheeled engines and the Fairlie engines, but undoubtedly the latter uses less fuel than the former in doing the same amount of work. Although these 8-wheeled engines are very well built and do good work on the line, they are nevertheless not able to take on the gradient of 1 in 125 a train of more than 32 loaded wagons in summer and 30 wagons in winter, or a gross load varying from 484 to 516 tons. This is a serious obstacle for the successful traffic, because on the whole line, except these 10 miles of gradient, trains of 40 loaded wagons are easily worked by the engines now in possession of the company. This impediment can be overcome by adding a second engine to pull the train up the gradients, but it is more economical to use one engine instead of two, and this can be done by working that part of the line where the gradient is situated, by a Fairlie engine.

UNARMORED SHIPS.

From "The Engineer."

The construction of efficient ironclad ships presents a problem, the solution of which becomes day by day more difficult. The battle which has raged between guns and plates since Sir Joseph, then Mr., Whitworth, drove a shot through 4 in. of solid plate on the side of H. M. S. Alfred, in 1858, has for the present resulted in the triumph of the guns. It is certain that we have not a single ironclad afloat that cannot be penetrated by shot and shell at close range, while the majority of our ironclads are not invulnerable save at a range of at least a mile and a half. Such a thing as an absolutely impregnable ship or turret has at this moment no existence. Nor has anything like the limit of destructive power in our guns been reached. Recent improvements in the manufacture, and, if we may use the word, in the construction of gunpowder, have opened up quite a new field for progress, and enabled us to use with success charges of heretofore unheard of weight. The 35-ton gun is an accomplished fact. That it can be manufactured with certainty, and worked with efficiency, no one doubts. Mr. Fraser long since expressed his conviction that he could make a 60-ton gun which should be as successful as the largest gun then in the service, weighing 18 tons; and there can be no doubt that if he gets the chance he will keep his word, provided he is supplied with proper plant. In a word, although we already possess guns which laugh at the heaviest targets afloat, these guns are not nearly the most powerful guns it is possible to construct and to use. But how stands the case with our ironclad ships? The limit of thickness in plates which can be carried on any hull of reasonable size has been practically reached long since, and we have been compelled as a nation to reduce the area to be protected, by adopting the turret system and cutting down the freeboard of our ships of war, the Glatton representing the best that can be done in the way of combining defensive with offensive powers. Even though it were possible to coat our ships or monitors with plates which would defy guns used in the ordinary way, we should be as far from the desired end as ever. A new danger, which, beginning like a cloud as big as a man's hand, has gradually loomed up till it covers the whole face of the sky, has to be dealt with. The torpedo has risen from the rank of a scientific toy to that of one of the most powerful implements of naval warfare, and no one in his senses can doubt that but little stimulus is required to inventors to set them at work improving on existing designs and scheming new ones, with the result, and that not a distant result, of rendering the torpedo the most deadly enemy of an ironclad fleet. Nor does the force of the attacking party terminate here. There is yet another danger to be dreaded by the ironclad, namely, the action of submarine ordnance. A gun of very moderate size fired under water would at close range punch and send to the bottom the strongest ironclad we have afloat. The experiment was tried years ago with the most perfect success—a success so great, indeed, that it is only matter for wonder that the experiments were not continued.* Thus it appears that our best ironclads can be penetrated by shell both above and below water, while these are liable at any moment to have great chasms

* Vide Evidence of House of Commons Committee on Ordnance, 1863, page 107.

blown in their bottoms which would send them to the bottom almost in the twinkling of an eye. We are not alarmists; we do not wish to make facts appear worse than they are; but we venture to say that there is not a reader of this journal in existence possessing a competent knowledge of the subject, who will not admit the accuracy of our statements and the truth of the deduction which we draw, to wit: That armor plating totally fails in the object for which it was intended. It can secure the safety of either crew or ship only for such a time as an enemy refuses to avail himself of the means of attack placed at his disposal by modern science.

Is it not time for the shipbuilder and the designer of ships to pause under these circumstances and set their houses in order—to consider whether there is not a way of escape—to determine whether it is or is not possible so to design the fleet of the future, that if they cannot defy the gun and the torpedo, they may at least render them as powerless as possible? The problem is enormously difficult, but, within certain limits, it is not, we think, absolutely impossible of solution. The solution, we believe, will lie, not in the extension of armor practically useless, but in the abandonment of armor almost altogether, and the construction of a different type of ship from any of those now in fashion.

As regards the attack of guns firing shells, it is obvious that unless armor keeps out such projectiles altogether it is worse than useless, simply because it renders the explosion of shell a matter of certainty. If ships were constructed with very thin and tough upper works, they would offer so little resistance to shells without fuzes, that the shell would pass in at one side and out at the other without exploding; of course the projectile would carry ruin in its track, but then its track would be so limited that the ruin would be of little moment. Ironclads cannot mount many big guns, and, as a consequence, the effect they would produce on an unarmed foe, by even a prolonged cannonade, would be less than that done by one of our old 120-gun ships in a single broadside. It will be urged that percussion fuzes would be used; but the percussion fuze for big shell is still a very imperfect affair, and the chances are that a large proportion of the shells used with such fuzes would either explode prematurely or not at all; in any case, nothing is gained in this respect by the use of armor. On the other hand, the suppression of armor plates would enable us so much to augment the engine power and coal space of our ships that they might maintain an unparalleled speed for days together, while they might carry guns of enormous power. Under these circumstances they could simply set torpedo boats at defiance; they could choose their own distance and keep just so far out of danger as they thought proper, disabling an enemy with their great long-range guns, while he would be powerless to inflict any injury. It is useless to urge that the enemy might be not only armored, but fast, and provided with big guns as well. This is impossible; we cannot combine immense speed, heavy armor, and huge guns in the same hull. We have not a ship afloat, which could not be defeated by an unarmored man-of-war capable of steaming 17 knots, and mounting a couple of 50-ton guns of sufficient length to enable them to burn all their powder in a bore of moderate diameter.

As regards torpedoes anchored, there is not so much to dread after all as some people think. It is known that the range of the torpedo is very limited, and the use of booms and torpedo nets would probably allow any fleet to pass without much loss through a channel protected with torpedoes alone. In any case, the unarmored ship would be quite as well off in this respect as the armored ship. The floating or missile torpedo is the really dangerous weapon; and the best protection against this engine of destruction is probably great speed in the ship attacked. But the unarmored vessel has further an element of safety at her disposal which the armored ship cannot have. There is so large a margin of buoyancy left at our disposal by the suppression of the plating, that it becomes easy to divide the whole bottom of the ship into numerous watertight compartments. A vessel built as it is quite possible she could be built, might receive the attacks of even 2 or 3 torpedoes with comparative impunity, while an ironclad—and especially a monitor—would go to the bottom like a stone.

All things considered, we believe that the day for ironclads has passed away.

That a few will still be used for attacking ports and defending harbors, is almost certain, but these ironclads will not be in any sense sea-going ships. The ocean battles of the future will, for anything we can see to the contrary, be fought by ships as free from armor as a Cunard steamer. The moment it is demonstrated that armor will not absolutely repel shot, it must be regarded as an objectionable incumbrance. So long as it really fulfils the purpose for which it is intended, it confers advantages which are worth obtaining, even at the sacrifice of almost every other qualification a ship of war should possess, except the power of fighting heavy guns; but it has been proved, as plainly as any fact can be proved, that such armor as a sea-going ship can carry, will not keep out the projectiles of guns of even moderate power, while it leaves the whole question of dealing with submarine attack absolutely unaffected, except in so far as it is a positive evil.

PRIVATE GAS MANUFACTURE.

From the "Journal of the Society of Arts."

One of the latest inventions for the purpose of enabling small consumers to manufacture their own gas, is that of Mr. Symes, who specially claims for his apparatus that it affords an opportunity for almost everybody to make their own gas. He claims, where the consumption is that of 25 lights, that his Patent Portable Gas Apparatus gives the consumer the power of making his own gas at a cheap rate. The first cost of the apparatus, from 25 up to 30 lights, is said to range between 20 and 25 shillings per light, the rate decreasing with every increase of light. Made from "slack," the cost of the gas is reckoned at a shilling per 1,000 cubic ft. Made from coal at 18s. per ton, with 10 per cent. of cannel, the cost is given at 2s. 2d. per 1,000 ft. The illuminating power is reported as equal to 18 candles or more, while the purity of the gas is stated to be perfect. At a recent trial, the gas was produced in a small iron retort fitted into what resembled an ordinary stove, the fire which heated the retort being also available for ordinary domestic purposes. A boy shovelled in about 3 lbs. weight of rather indifferent coal, and the door of the retort was then closed, fitting gas-tight into its place without any ceremony of "luting," that is to say, without any plastering up of the door of the retort to prevent the escape of gas. Within a few seconds from the closing of the retort, the gas began to flow out of the burners, and burned brilliantly, the number of the flames being increased as the coal underwent distillation. It is not absolutely necessary to use coal, or coal alone—bones, wood, or peat, being available. Peat, however, gives a weak gas. On its way from the retort to the burner, the gas passes, first of all, through water, which deprives it of certain impurities, after which it enters a condenser where the tar accumulates, and from whence this material can be readily drawn by means of outlet pipes. At the foot of the condenser is the purifier, and thence the gas proceeds into the gasholder. The space occupied by the apparatus is very moderate, the bulk depending mainly on the size which is thought desirable for the gasholder. The erection of the affair is within the compass of an experienced gasfitter. The process of manufacture is so automatic that a domestic servant once instructed could manage it with quite as much facility as the machinery of a kitchen range. All the solid refuse of the house which happens to be of a combustible character may be turned to account. The design of the invention is to provide individuals with a supply of gas where the smallness of demand precludes the operation of a regular gas company. Mr. Symes is also prepared with a modification of his apparatus for use on board ship. The following is a technical description from the specification of the patent, the purpose of which is the supply of cheap and pure gas to churches, hospitals, private houses, shops, offices, warehouses, factories, and other buildings, as well as to steamboats, railway carriages, signal ships, lighthouses, etc. As to the generation of gas, it is preferaple to do it from wood; but coal, paper, peat, resin, "dead oil," and, in fact, almost any material may be used.

It should be distinctly understood that no part of the invention relates to the use of any particular substance or compound for producing the gas or for burning wood, etc. The apparatus is provided with a circular box or retort of iron, or other suitable material, which may be placed in a kitchen range, or in any ordinary stove. The form of this box or retort allows it to be surrounded by the fire, and quick and economical production of gas is thereby obtained. The box is perfectly closed by a cover, fitted with a face like a valve, instead of being made tight by means of lime or cement, as in ordinary gas retorts. The retort is connected by a pipe or tube to a hydraulic main, which may be placed in the chimney, or arranged and supported in any convenient position in or near the house or structure. This vessel is partially filled with water, and the pipe or tube which connects the retort with the hydraulic main has one opening above the water, and another below the surface. The hydraulic main is provided with a safety valve, and when the pressure in the retort rises above a certain degree, the safety valve is forced open, and the gas escapes into the chimney, or into a pipe or passage leading thereto. Except when the safety valve is open, the gas leaves the pipe through the opening below the water level, and the apparatus will thereby work with a pressure considerably less than if the gas entered the main above the water. The exit pipe for the gas is at the top of the hydraulic main, and the tar pipe is at the end or side thereof, level with the surface of the water. The main is provided with a covered aperture for pouring in the water, and with a tap for permitting it to escape. By this means the level of the water in the main can be so regulated as to insure the continual proper working of the apparatus. The gaseous products of combustion received from the retort into the hydraulic main are by the latter separated, so that the gas passes away through the exit pipe, while the tar and other impurities, except the sulphur, are carried off by the tar pipe, which terminates in a larger tube, or cylindrical vessel, arranged below the main. The hydraulic main is connected by the gas exit pipe to a condenser, which is a vessel having within it a series of vertical partition plates, so arranged that the gas passes alternately over and under the other until it leaves the condenser. The latter is connected to a purifying vessel, which is divided vertically into two chambers, in one of which there is a series of sieves containing lime, and in the other similar sieves, with sawdust, sand, or other suitable material. The gas, as it enters the purifiers, passes up through the lime, and enters the second chamber, and descends through the sawdust, thence passing, free from sulphur, away through the pipe to the gas-holder. This gas-holder is preferably a cylindrical vessel, which may be made of sheet iron, zinc, etc., and is partially filled with water. It may be made of any required capacity. Inside the gas-holder is an inverted chamber, which opens into the water, and which rises and falls in proportion to the quantity of gas in the holder. At the top this interior vessel is provided with a small tube, which passes through a guide at the top of the holder; it has also a burner attached, whereby the quality of the gas in the holder can be tested at any time. Instead of using a cylindrical metal gas-holder, an air-tight bag, made of india-rubber, gutta-percha, leather, or other flexible material, may be used. In cases where it is desirable to increase the brilliancy of the light, a small carburetting vessel may be provided, this being partially filled with undistilled naphtha, or other carbonaceous liquid; the gas passes from the gas-holder in the vessel, where it absorbs carbon, and consequently increases the power and brilliancy of the light.

Sooner than was expected, a commencement has been made in filling the new factory basin at Chatham Dockyard Extension with water, which is admitted by culverts from the first or repairing basin. There is already a good depth of water in the new basin, but it will be some time before the full depth of water has been admitted. There is still a good deal to be done at the works. The third or fitting-out basin will not be completed for a long time; factories and workshops are to be erected, and two docks abutting on the repairing basin, are to be completed. In spite of some delays caused by irruptions of water and the troublesome nature of the soil, these docks are now well advanced.—*Mechanics' Magazine.*

PRE-HISTORIC FORTIFCATIONS.*

By. Mr. LAWSON TAIT.

Mr. Tait, after some introductory remarks, observed that weapons began to be used before any definite scheme of fortification came into use. The use of the stick or the sharpened stone commenced at a much earlier stage of the history of armature than the use of fortifications. The first indication of fortification was what they might naturally expect, viz., a fortified hillock, men finding that upon an elevated position they had an advantage in the use of their weapons. Thus they found that the earlier fortifications were hill forts. The well-known Roman forts with which this country abounded were not such as he classed amongst pre-historic fortifications, because pre-historic meant such as they had no historic knowledge of. In the earliest times, he believed that the structures of which he was going to speak were not intended for permanent residence, as forts now were. The huts of the village were generally on the outside, at a short distance from the fortified hillock. There was one instance in which the huts were inside the fortified enclosure. The lecturer then proceeded to make some remarks upon the fortified rock at Rhun in Strathfleet, Sutherland, which was the earliest type of any he had been able to see. So skilfully was this fortress constructed on the hill that its existence was never discovered until a sportsman shot a bird and saw his dog disappear over the rude wall which surrounded the enclosure. This fort simply consists of a space in the top of the rock enclosed by walls, the doorway being on the side which was most accessible. When there was an alarm the people from the village probably went into the enclosed space for protection, but it was evident that such forts were not intended for long occupation, as there was no place for the stowage of provisions. In those days, however, warlike incursions must have been of short duration. They came to other fortifications of more definite arrangement. The fortified rock in Sutherland, to which he had called their attention, and of which there were other instances, evidently belonged to the stone period—the period when men had to use stone arrow heads, stone hatchets, and stone hammers as weapons. The structures of which he spoke might all be relegated to the stone age, for although in some cases two or three small bronze implements had been found in them, they were of such kind as to lead them to the belief that these were there through accidental circumstances. There was no doubt that these structures were after the stone age occupied by men of the bronze age, as they were handed down as national property. After the enclosures, which were simply surrounded by a wall, they came to structures which were evidently intended for more permanent residence, there being chambers for the storage of provisions. These chambers were of great interest, as they showed that the people who made them had taught themselves how to form Cyclopean arches, which were not confined to Greece. In the first instance, there was was only one chamber in the structures, and this chamber was always on the same side of the doorway. This single chamber, he thought, was made to contain the rubble required for fastening up the doorway when there was an attack. The other and more extensive chambers were, however, undoubtedly for the storage of provisions. In one of the chambers in one of these structures in Sutherland the skeleton of a man was found, and amongst his bones was found a "quern," or grinding mill, and in it some grain. Mr. Tait then pointed out that the fortifications were placed in such positions that the people could carry on a system of telegraphy. So nicely had they been arranged that he had been puzzled to discover the two corresponding towers, until he had got upon the elevation, which exactly corresponded with the original height of the tower. The amount of surveying the people must have gone through certainly must have entailed great labor. After speaking of several pre-historic remains to be found in various parts of the country, and illustrating his remarks by reference to a large number of diagrams, Mr. Tait called attention to the fact that no one had "taken up" the pre-historic remains in Warwickshire, and then made some remarks upon the mound which they

* From an address before the Midland Institute.

saw at Brinklow during their excursion. He said his impression was that there was no fortification at that place which belonged to either Saxon or Celtic times, or was entitled to rank as of great antiquity. He thought the fortifications there were too extensive and too well done, and had none of the marks of the ancient fortresses to which he had drawn attention. If there were any they had escaped his notice.

RECENT PROGRESS IN MECHANICAL ENGINEERING.

From "The Engineer."

In mechanical engineering it is but right that the first place should be given to the steam engine. As regards the past year, it may be stated with perfect truth, that no improvement whatever has been effected in steam machinery. This may appear to be a very sweeping assertion, and it is therefore necessary to explain our meaning as precisely as possible, to avoid any misapprehension. What we intend to convey is that the most economical engines built during the year are not more economical than engines built long since; but it is probable that a greater number of really excellent engines have been built in 1871 than were ever constructed in any previous year. This is, of course, in a sense, progress, but it is not progress in the highest and truest sense; and it is worth while to place a few facts concerning the theory of the steam engine in a proper light, in order to show in what direction we must seek for improvement.

In the first place, then, it is impossible to take up a good text-book on the steam engine without finding a more or less elaborate "theory of the steam engine" enunciated; nevertheless, we hold that something concerning the true theory of the steam engine has yet to be decided, and we base our belief on plain facts. All the knowledge which we possess of the properties of steam, the laws of expansion, liquefaction in doing work, condensation, etc., is founded upon the investigations of a very limited number of experimenters, among the most important of whom may be named Regnault, Fairbairn, Tate, and Unwin, Siemens, Dulong, and Petit, and a few others. All the experiments conducted by these gentlemen were performed in the laboratory, or at least on a very small scale. The results they obtained have formed subject-matter for elaborate disquisitions by numerous mathematicians, who have supplied the world with plenty of numerical examples of the work which ought to be got out of a given quantity of steam. One of the best treatises on the steam engine that has ever been published* lies before us. At p. 33 we find a table showing the number of pounds of steam required to produce 1-horse power according to theory. The figures are as follows:

Pressures in Atmospheres.	Condensing.	Non-condensing.	Temperature.
	lbs.	lbs.	
2	11.2	50.4	249
4	9.2	24.8	291
6	8.3	18.9	318
8	7.7	15.9	340

In the case of the condensing engine it is assumed that the feed is thrown into the boiler at a temperature of 100 deg., and in the case of the non-condensing engine that it is introduced at a temperature of 212 deg., derived from the exhaust steam. We have every reason to believe that these figures are quite correct; it will be seen that they refer to the quantity of steam passing through the engine, and they have nothing to do with the efficiency of boilers or of fuel. Now as a matter of fact, in practice no engine in existence gives out anything nearly approaching this result. There is not, and never has been, an engine constructed, which, with any pressure or rate of expansion, has developed 1-horse power by the use of 11.2 lbs. of steam. It is quite true that, as Mr. Cotterell very properly points out, one main cause of the difference between the results obtained in practice and those which in theory ought to be had, lies in the fact that we cannot carry expansion sufficiently far to reduce theory to prac-

* "Notes on the Theory of the Steam Engine," by F. H. COTTERELL, M. A. London: Spon. 1871.

tice; but this being granted, there still remains a large margin of wasted efficiency to be accounted for; and an explanation is also required of the reasons why expansion cannot be carried far enough. As to the first point, it will suffice to point out that if a steam engine working with 8 atmospheres—or say, in round numbers, 120 lbs. on the sq. in.—will in theory give a horse power for every 7.7 lbs. of steam passed through it per hour, we might expect that in practice it would perform as well as a theoretical engine working at a pressure, in round numbers, of 30 lbs. per sq. in., and so give out 1-horse power for every 11.2 lbs. of steam going through it per hour; but, as we have said, such a result has never been obtained from any engine in practice. As regards the second point—that is to say, the limitation of the degree of expansion—information is required as to the limiting causes. It will not do to urge that they originate in the difficulty of getting machinery to stand a high initial strain and to maintain an invariable speed. It has been proved that long before the limit is reached in this direction economy ceases, that is to say, nothing is gained by expanding steam beyond a certain point, and this point is reached long before much trouble is incurred from irregularity of action due to varying pressure; and this, strange as it may seem, holds true whether the cylinder is jacketed or not. The fact is that the experiments carried out with so much care and skill in the laboratory, do not apply accurately to the case of the steam engine in which enormous volumes of steam are used; and, as it has been pointed out before this, it is quite possible that the results obtained in the laboratory are vitiated by the small dimensions of the apparatus employed. Not a single instance can be cited in which the results of elaborate experiments with steam engines of considerable dimensions tally even approximately with the laws laid down in text-books. Either the laws are erroneous or there is some peculiarity about steam which causes it to differ much more widely than is generally believed, in its behavior, from that of a permanent gas. Lest it should be thought that in saying this we speak "without book," we may cite a few facts to which our readers will attach the importance they deserve. Mr. Isherwood, while chief of the United States Bureau of Steam Engineering, carried out an elaborate and exhaustive series of experiments on the use of steam in various ways. We have before now had occasion to criticise Mr. Isherwood's theories; but it is next to impossible to dispute some of his facts. One of these is, that by using superheated steam he obtained a large measure of economy, saving something like 30 per cent. in fuel; but he also found that if when using saturated steam with a certain measure of expansion, and without expansion, the difference in the total cost per horse-power was a certain percentage in favor of expansion; then when he used superheated steam in the same way without expansion and with expansion, there was a difference in favor of expansion, but this difference was precisely the same, whether the steam was or was not superheated. Now, seeing that superheating prevents condensation in the cylinder, and that cylinder condensation is the great enemy of expansion, it seems to be clear that the comparative efficiency of the steam—in other words, the economy of fuel—should augment as the expansion increases, in the case of superheated steam; but, as we have said, no such result was obtained. If this were an isolated case we might reject it; but we can produce corroborative evidence from a totally different quarter. MM. Nolet et Cie., of Ghent, have for many years been celebrated as successful builders of engines for driving cotton mills with extreme economy. Within the last few days we have been favored with a letter from M. Nolet, the contents of which we do not feel ourselves at liberty to make public. It will suffice to say that M. Nolet carried out some time since an elaborate series of experiments to test the value of the steam jacket. The results at which he arrived satisfied him that there is no advantage to be derived from the steam jacket, and that, further than this, his engines without the jacket are more successful than those with it. With or without, the engines rank among the most economical in existence; so that it cannot be argued that they were such large coal consumers from other causes that a jacket here or there made no difference. We may also point out that we have received letters from one of the most influential builders of compound engines, stating that the results obtained at sea when steam was shut off from the jacket differed very little indeed from those obtained with steam in the jackets as regards economy of fuel. One leading mechanical engineer, building compound engines for ocean steamships, regards the jacket as an unnecessary refinement. In the case of the Cornish engine, jacketing the lid has been abandoned, because the saving in fuel due to its presence was not found to be worth the trouble of making and unmaking a joint every time the lid had to be removed ; and, finally, we may point out that the large cylinders of compound engines are rarely jacketed, as it has been discovered that little or no condensation takes place within them, although they are exposed to the full action of the condenser, and present the largest surface to steam of the lowest pressure.

It may be urged that in writing thus, we are inconsistent ; that we have recently devoted much space to maintaining the value of the steam jacket against all comers ; and that, in a word, we blow hot and cold. There is no real inconsistency, however. Our advocacy of the steam jacket is based on the received theory of the steam engine, and, until that theory has been demonstrated to be susceptible of modification, we shall continue to maintain that the steam jacket is right in principle and essential to economy. At the same time, however, it is our duty to call attention to the fact, that in certain cases, for reasons not clearly understood, practice is directly opposed to the theory of the steam engine, even though such a statement militates against our own views ; and this leads directly to an explanation as to what our object is in writing as we have just done about the steam engine. It is our task just now to indicate the direction in which progress should be made during the coming year, and we earnestly desire to see some competent individual, or firm, or society, set on foot a series of experiments with a good steam engine of not less than 100-horse power indicated, which will determine in the first place, and if possible once for all, what is the true value of the steam jacket, a point about which no one is able or willing to supply a scrap of accurate detailed information derived from practice ; in the second place, the true value of different measures of expansion and piston speeds ; and, lastly, the value to be obtained from different systems of lagging cylinders and steam pipes, and the true amount of condensation which takes place within unclothed steam pipes and cylinders as a result of conduction to the bed-plate, etc., and radiation and conduction to the atmosphere. Such a series of experiments would cost a considerable sum, but they would be well worth the money. Let us suggest that the Institution of Mechanical Engineers in Birmingham take the matter up. We have no doubt that they could easily secure the co-operation of most of the leading firms of engine builders in the country, and thus the expense of the experiments being divided, it would not press heavily on any individual or firm.

Turning back to the past, the marine engine first claims a word. During the last year there has been an unparalleled demand for compound engines. Every house in the trade is overwhelmed with orders. But the fact in no way alters the opinions we have long since expressed. For low measures of expansion we hold the compound engine to be a mistake, and few even of the most enterprising modern builders venture to expand their steam beyond 6 or 7 times. The truth is that there is a fashion in steam engines as in everything else, and, compound engines being for the moment the rage, they are supplied at, we hope, remunerative prices. Already, however, we begin to hear complaints that the wear and tear, and complexity and trouble incurred at sea, more than counterbalance the advantage gained in economy of fuel. Of course the compound engine working with 60 lbs. steam expanded 5 or 6 times, is more economical than the now old fashioned type of engine working with 20 lbs. or 25 lbs. boiler pressure, and cutting off at $\frac{1}{2}$, or at most $\frac{5}{8}$ths stroke. But the economy of the new engine is not due to compounding, but to the high pressure and measure of expansion, and also to the improved type of boiler which, in addition to offering more surface for the power developed, is fed with distilled water, and as a consequence, always practically clean. The compound engine will run its course, and then settle down into its proper place, which is not at sea.

In locomotives nothing remarkable has been done during the year ; our own working drawings have kept our readers well posted up in the most recent practice. Mr. Stirling's great engine, with drivers 8 ft. 1 in. in diameter, and cylinders 18 in. by 28 in., cannot be said to have originated in 1871. We this week publish a working drawing and specification which supply the best possible information concerning recent practice in a totally different type of locomotive. We cannot resist the temptation to avail ourselves of the opportunity to thank the various locomotive superintendents of different lines, English, American, and Continental, for the courtesy with which they have placed their working drawings at our disposal. As regards American locomotives in particular, we shall at an early date supply some elaborate engravings of certain examples of the United States locomotive, illustrative of the most recent practice on one of the most important lines in that country. We have no small pleasure in stating that a type of engine first brought before the public in this journal, and persistently supported by us through evil report and good report, as being correct in principle and likely to supply a great want, has during the year taken the position it deserves. We allude to Mr. Fairlie's double bogie engine. Locomotives of this type are now being built, principally at the Avon Side Engine Works, for the Pesaqua, the Iquique, and the Mexican Railway to 4 ft. 8½ in. gauge; for a railway in Switzerland, with grades of 1 in 25, also 4 ft. 8½ in. gauge; for the Arica line, 2 ft. 6 in. gauge; for the Dunedin and Port Chalmers Railway, 3 ft. 6 in. gauge; for the Cape Breton Railway, 3 ft. gauge; for the Toronto, Gray, and Bruce line, 3 ft. 6 in. gauge; for a railway in Rio, 3 ft. 7½ in. gauge; while in America, Fairlie engines are being built by Porter, Bell, & Co., and by W. Mason for the Taunton and Maine line. In Russia the system has been fully adopted. Mr. Fairlie has had much up-hill work to overcome prejudice, and he fully deserves his success.

The use of steam on common roads has made great strides during the past year, and it is but fair to Mr. Thomson, of Edinburgh, to state that much of this progress is due to him. Let what will be said on the subject of india-rubber tires, it is day by day becoming more evident that an elastic wheel of some kind is essential to the full success of the traction engine or road locomotive. One of the great objections to its use hitherto urged against it has been the extremely slow speed at which alone it could travel. A nominal velocity of 4 miles an hour really means, when all deductions are made for the delays incurred by stopping for horses, taking in water, etc., a rate of not more than two miles an hour. This does not tell heavily in one sense against loaded engines, but it greatly increases the cost of working them, in that, in returning light for a second load, the duration of a trip is unnecessarily prolonged. A traction engine, to be really efficient, should be competent to travel, when it gets a chance, at 6 miles an hour; more is unnecessary for ordinary work. This speed cannot be obtained without springs of some sort. It is, however, very inconvenient to apply springs in the ordinary way to the driving wheels, for reasons too obvious to all builders of such machines, to require comment; and it must further be remembered that, even if this were not the case, the duties of a spring are but half performed when the spring is located between the engine and the axle. A 6 ft. wheel of sufficient breadth, to be strong enough, will weigh about 18 cwt., in some cases as much as 22 cwt. It is not too much to say that the dead weight, unaffected by the use of springs, will therefore amount in a 12-horse power traction engine to rather more than two tons, which is highly objectionable. The only way out of the difficulty lies in placing the spring at or in the tire of the wheel, and the success which has attended Mr. Thomson in his labors is due to the fact that his india-rubber tire exactly complies with this condition. The great objection to india-rubber lies in its enormous cost—over £100 for a moderate sized engine—and the uncertainty of the material. Thus the Ravee on her wonderful trip from Ipswich to Edinburgh and back, recorded in our pages, rendered one leading tire useless on her journey to the north, and she disabled another on her journey to the south. As these tires cost about £50 each, we have an outlay of about £100 for a journey of 900 miles, or a cost of 2½s. 2d. per mile for tires alone. The ruin of the tire in this case was, no doubt, mainly due to the heating of the rubber caused by the high speed maintained.

In regard to electricity, we may here glance at one of the most neglected of its modern developments, which is now beginning to attract attention in certain quarters. The sisterhood of chemistry and electricity has been recognized ever since the latter became a science; but the close relationship of both to mechanical dynamics, although known in theory, has in practice received such scant recognition that very many scientific engineers might at first almost regard as an impertinence such questions as—"How many horse-power would be required to convert in 60 hours a ton of lead into one ton two cwt. 57 lbs. of plumbic peroxide?" or "How many foot-tons of work might it take to reduce electrically the metal in a ton of malachite?" Yet from the direction which electrical theory has taken, more especially during the past year, and from that which practical endeavors are now taking, it appears more than probable that the dictum which asserts that all physical science is one, will receive a verification in the future by the constant reference to engineering authority upon questions which would until now have been regarded as utterly beyond the province of the engineer. We know, in fact, that whilst the steam engine is a device for the conversion into mechanical work of the potential energy of chemical separation stored up in coal and other fuels by solar agency, the beautiful and comparatively recent magneto-electric machines of Wilde in England, and of Gramme and others on the Continent, are contrivances for the conversion of mechanical work into electrical energy. But the practical physicist is, moreover, now beginning to understand with what facility, and with what probable economy in certain cases, the electrical energy thus obtained may be converted into chemical work—how the steam engine can, by means which are dependent upon the correlation of all modes of energy, tear asunder and rearrange the atoms and molecules of compounds, so as to convert them into others, or to resolve them into elements of higher utility and value. Not very many years ago it was attempted to do this by means of the oxidation of zinc in a voltaic battery under economical disadvantages, which may be estimated from the fact that the indirect electrical work of 1 lb. of coal consumed in the furnace of a Cornish engine is, or should be, with a well constructed magneto-electric machine, about equal to that of 1 lb. of zinc consumed in a Daniell's battery, *i. e.*, to one million foot-pounds nearly. With this datum and Faraday's law of definite electro-chemical action, the engineer will require only to know, in terms of Daniell's cell, the electromotive force necessary to effect a given chemical reaction, in order to be able to calculate the expenditure of mechanical energy requisite to apply this reaction to a given weight of material; and he may thus determine what chemical operations may profitably be carried into effect by the combined agency of the steam engine and the magneto-electric machine.

THE MANUFACTURE OF LARGE MASSES OF IRON IN INDIA.

By GEORGE M. FRASER.

From "The Engineer."

Mr Mallet's article in "The Engineer" of the 15th ult.,* on the very singular iron column within the mosque of the Kutab, near Delhi, is one which cannot fail to be particularly interesting to all students of the history of iron metallurgy, and is certainly in great measure exhaustive and complete. Mr. Mallet, however, whilst coming to the conclusion that this monument is of malleable metal, seems yet inclined to suggest the possibility that at some distant date the iron workers of India may have had a knowledge of iron in its liquid form which at present they do not seem to possess, and of which knowledge history affords us no record. Mr. Mallet's great difficulty—and at first sight there can be no question that it is apparently an insurmountable one—is that—assuming

* See page 116 of the present volume.

the column to be of wrought iron—of forging such a mass of metal at a welding heat by the mere manual power within reach of Indian iron workers at the supposed date of its manufacture. The experience of many years spent in charge of an iron works in Southern India, where cast-iron was produced by the European method, but which experience also comprised constant intercourse with the native smiths of the country and a knowledge of the material they used, and of the method of its production and capabilities in manufacture, may perhaps entitle the present writer to offer what he ventures to believe will be considered by practical men a satisfactory explanation of how such material, labor, and capabilities might have been used to produce the column now under notice.

In the first place, then, the writer would record his decided opinion that the column of the Kutab is of wrought, or at all events of malleable iron; for during the whole course of his Indian experience, which included many visits to the native smelting furnaces in the Salem and Malabar Collectorates, together with the constant practice at his own works in the production of *edged*, not *chipping* tools, of the native steel, he never found anything approaching an attempt to *tap* one of these furnaces, nor heard any Indian workman speak of cast-iron but as of a material utterly useless to him, and beyond his ken.

The process of smelting, as pursued in Southern India, is probably sufficiently well known not to require any further description here, than, that in a perpendicular circular furnace about 6 ft. or 8 ft. in height, and of a diameter at its greatest width of about 18 in.—the blast to which is supplied by the alternate inflation and compression of 4 or 6 goat skins worked by hand, as in the ordinary smiths' fires of the country—the black magnetic oxide so common in the laterite formation is converted, not into cast iron, but rather into a mass somewhat similar to the loup of the Catalan forges, presenting in parts a crystalline and in others a fibrous fracture. The removal of these lumps—mootees they are called by the natives of Malabar—or loups, necessitates the breaking open of the whole of that part of the little furnace which corresponds to the timp and fore hearth of an English blast furnace; and in order to prepare for this, the charging at the top is stopped, as is also the blast, and the whole contents allowed gradually, as combustion exhausts itself, to sink down into the hearth, whence, when cool, it is removed. These loups or mootees (the writer must object to Mr. Mallet's term "pig," as applied either to these or any result of the cementation process, as the term certainly conveys, to English ears at least, the idea of cast iron) are generally from 80 lbs. to 112 lbs. in weight, and it is from the building up of lumps of metal, such as these, one upon the other, with such reheating and hammering as may have been found necessary to effect cohesion, that the writer conceives the Kutab column to have been produced. He cannot think that there is anything impossible in such a mode of proceeding, nor anything in the actual working of the material—which is of a most malleable nature, and weldable at a very low comparative heat—which the native smiths are unequal to performing. Fifteen inches diameter is certainly a very, very large bar; but it should be recollected that in the process just suggested it would only be the surface of each successive mootee (previously, of course, heated and hammered to the proper section) which would require to be at welding temperature for such surfaces might readily be produced in good charcoal fires without much injury to the iron so treated. The writer has himself seen shafting of between 6 in. and 8 in. diameter heated in open fires composed of charcoal and "bratties" (sun-dried cow-dung), and welded to good joints by native smiths in the Madras Presidency. Conceiving, then, that the column may have been thus built up—and of course this supposition is directly opposite to the idea that it might have been composed of longitudinal bars welded together—we find the capital left to be accounted for; and the very form of this, is one which could readily have been produced by swaging, and finishing with such chipping (but this only to a small extent, the writer believes), as may have been found necessary. It is also to be recollected that the column itself has never, save, of course, in the act of raising it, been submitted to any severe strain, and that its cohesion has never in any way been tried in tension, as is ordinary shafting. Further, the extraordinary amount of quiet perseverance with which the natives of India are endowed, and the illimitable amount of mere manual labor which any great Eastern ruler could bring to bear upon such an object of ambition as the construction of a trophy or monument as this column may be considered, would all go to help us to the conclusion that this huge rod of iron may have been manafactured in such manner, and with such material and appliances as the writer has described.

Again, it may be remarked that, even supposing other similar columns to exist, as Mr. Mallet seems to think, yet even this very existence, in so confessedly small a number, proves them to have been quite exceptional productions, and not in any way portions of a systematic manufacture of large iron forgings. It is, too, a point well worthy of notice, that there would seem to be no examples left of what might be described as the intermediate stages of iron-working; *id est*, examples of forgings, which, whilst exceeding greatly in size and weight the present ordinary productions of the Indian iron smiths, would yet be of far smaller dimensions in every way than this column of the Kutab; for the large beams mentioned by Mr. Mallet can scarcely be classed in this category. The writer is, therefore, forced to the conclusion that this, and also the similar column spoken of, must be regarded as purely exceptional productions—types of no manufacture ever extensively or usefully existing in India, and indicating neither the possession of machinery calculated to produce such types in any number, nor even much smaller forgings. Exceptional, however, as they appear to be in every way, he yet ventures to believe he has pointed out the process by which, in all probability, they were manufactured; and if they can be regarded but as mere monuments of some now nameless ambition, they are yet wonderful examples of that ant-like perseverance and patient industry which in many ways mark the metal workers of India.

COMPASS COMPENSATION ON IRON SHIPS.

From "The Mechanics' Magazine."

M. Arson, engineer to the Paris Gas Company, has studied the variations in marine compasses, and designed an apparatus to compensate for the same in all latitudes, based upon the investigations of the mathematician, Poisson, and Mr. Airy, the Astronomer Royal.

Mr. Archibald Smith has already deduced from these theories practical rules, by the aid of which skilled mariners can compute, with a few observations, a numerical table of corrections to be applied to the observed compass-bearings; and Admiral Napier introduced the representation of the series of observations by a curve interpreting the indications of the needle.

But these methods are scarcely within the reach of ordinary navigators, on account of the delicacy of the observations required for the table or the curve; and, moreover, the resulting corrections are only applicable for the latitude of the original observations, and to the needle with which they were made, and therefore fail in general accuracy and application.

M. Arson, however, has sought, by special appliances, separate compensations for permanent and induced magnetic action, so that the compass shall act as if solely influenced by terrestrial magnetism.

It is well known that all the separate pieces of iron that enter into the construction of the ship, the machinery, fittings, cargo, and armament, having undergone certain mechanical treatment, possess certain permanent magnetism, independent of position, of invariable intensity; and, in addition, they are endued, by the inductive action of the terrestrial globe, with a transitory magnetism, varying according to their position on the earth's surface.

To compensate for the effects of permanent magnetism, M. Arson applies three bundles of magnetized steel wire, two of which are fixed horizonally under the compass, one in the longitudinal axis of the ship, the other transversely to it at right angles. The power of these magnets depends upon the number of wires, and may also be varied within certain limits by raising or lowering them, for which purpose they have a slight motion in vertical grooves.

Two stations in the same quadrant suffice to regulate this compensation, since while operating on one of the magnets at right angles to the needle, the other magnet, being parallel to the needle, has no effect.

The third magnet of wires is movable; for, inasmuch as the effect of the ship's permanent magnetism on the compass-needle varies with change of position, no arrangement of fixed magnets alone can compensate for it. Therefore, the two fixed magnets effect only a part of the whole compensation required; and if a curve is drawn representing the variations of the compass-needle due to the permanent magnetism of the ship in successive positions, and also, from the same co-ordinate axes, a curve of inverse deviations or compensations due to the fixed magnets, the differences between the ordinates of these curves supply the measure of the supplementary compensation required.

This, then, is the function of the movable magnet, which has a position appropriate to every change. It is attached perpendicularly to a horizontal axis at a point dividing its length unequally. This horizontal axis is originally placed in the true direction of the disturbing pole of the ship, determined by ascertaining the point in the revolution at which the needle is unaffected. By causing this axis to revolve, the magnet also revolves in a vertical perpendicular plane, and thus its poles may exercise a variable action upon the poles of the needle.

But, by a tentative process, M. Arson arrived at an arrangement that by the turning of the axis through an angle, the double of that of the evolution, the resultant of these actions for each change of position becomes equal to the deviation that remains to compensate for the difference between the curve-ordinates referred to. A bevel-wheel fixed upon the horizontal axis is actuated by a horizontal bevelled pinion of $\frac{1}{2}$ its diameter, the vertical shaft of which carries a horizontal repeating circle against a fixed index corresponding in fact to the circle of the compass itself.

Thus, when following a course making a given angle with the magnetic North, all that is necessary is, to turn the horizontal circle until the index marks the angle of the proposed route, whereby the vertical magnet will have revolved through twice the angle, and will be so situated as to complete the supplementary compensation required to neutralize the effect of the permanent magnetism of the ship on that course.

In compensating for the induced magnetism of the iron hull, the engines and boilers, and the iron of the armament and cargo, M. Arson places on each side of the compass a bundle of soft iron wire, suitably proportioned. In sailing vessels, where the influence of hull predominates, the deviation is always negative in the N. E. quarter, and the 2 parallel bars are moulded on a support caused by horizontal gearing to revolve through an angle equal to the angle described by the horizontal axis of the apparatus; in a steam vessel, where it is the magnetism of the bodies carried that predominates, the deviation is positive, and the 2 bars are fixed upon the support of the apparatus. When these 2 bars have been regulated so as effectually to compensate for the magnetism of induction in any one position of the ship, they will compensate for it in all positions, and in all latitudes, because their magnetic condition undergoes changes in the same sense and degree as that of the pieces of iron in the ship, and consequently the equilibrium, once obtained, is permanent.

This invention has been applied on board the steam vessel Europe, of the Transatlantic General Steam Navigation Company, and it is most important and desirable that its efficacy should be thoroughly and completely demonstrated by practical tests and experience. If confirmed, the independence of the magnetic needle on board of iron ships will be restored to it, to the manifest advantage and security of all mariners and shipowners.

Levant Telegraphs.—The Telegraph Maintenance and Construction Company has completed the laying of the cables uniting the islands of Candia, Cyprus, Rhodes, Chio, Samos, and Mitylene to the mainland of Asia Minor.

MANUFACTURE OF GUNPOWDER DURING THE SIEGE OF PARIS.

From "The Engineer."

Towards the end of the summer of 1870 it became evident to the most enthusiastic partisans of the French cause that the almost unparalleled reverses which had attended it would culminate in the siege of the capital by the victorious enemy. Under these circumstances, prompt and urgent measures were at once necessary in order to insure to the anticipated besiegers an adequate supply of the material of war. Obviously gunpowder occupied a prominent place in the deliberations of the defenders of Paris, and it was at once determined to bring within the walls of the city as large a quantity of that indispensable article as could be collected on short notice. There existed several powder manufactories and magazines in the neighborhood of the capital which would inevitably fall into the hands of the enemy on his advance upon the city. These, it was resolved, should be evacuated, and their contents transferred where they could be rendered available during the impending siege. By these means the supply in the manufactory of Bouchet, a military establishment devoted to the production solely of cartridges and powder for war purposes, was removed out of the reach of the foe. Similar foresight insured the safe removal to Paris and Lyons of the contents of the magazines of Saint-Ponce and Vonges, which included a considerable quantity of mining and sporting powder. When these removals had been successfully accomplished there was upwards of 2,000 tons of powder available for the use of artillery, about 45 tons for the purposes of mining and military engineering, besides a certain quantity of sporting powder which was regarded in the light of a reserve, and only to be employed when matters came to the worst. It was calculated that, owing to these precautions, the citizens of Paris had powder sufficient to enable them to stand a siege of 3 months ; but when the capital was actually invested, and the forts maintained an almost incessant cannonading, serious doubts began to be entertained whether a consumption so excessive would not speedily exhaust the supply, abundant though it was. Again, the duration of the siege was extremely uncertain, and might be prolonged to a period that would render it indispensable to procure a fresh stock of ammunition at all risks. In the face of this contingency the wisest plan was clearly to set to work to utilize such materials as might be available for the manufacture of gunpowder. There could be no harm in having an excess of that article, but a deficiency would be attended with the most disastrous results. There was plenty of saltpetre in Paris—one of the essential ingredients—capable of being utilized at once. Moreover, since the commencement of the siege, several workshops had been established for the manufacture of cartridges, which afforded a considerable amount of employment to men and women, who, without such employment, would have become objects of public charity. A real advantage thus resulted from the maintenance of those workshops, which would cease directly the store of powder which was used in the preparation of the cartridges became exhausted, unless means were provided for insuring a fresh supply. It is true that gunpowder manufactured in what might be fairly termed an improvised establishment, and under very exceptional circumstances, could not be expected to be of so good a quality as the same article produced under the normal state of affairs. Nevertheless, there was no choice in the matter, so it was ultimately decided to commence the undertaking in premises situated on the Boulevard de Phillippe-Auguste, in the neighborhood of the Barrière du Trône.

Before proceeding to describe further the method of manufacture carried on in this particular instance, it will be interesting to review some of the methods that have been adopted, when the ordinary one has, for some cause or another, been unavailable. Numerous explosive substances are known to chemists and pyrotechnists, the action of which is very analogous to that of gunpowder, and the effect of which is in many instances considerably more violent. The majority of these substances are of recent date. Gunpowder made with chlorate instead of nitrate of potash, is an exception, and it is with this that we shall commence. It is much stronger than ordinary powder, but, owing to its great disruptive power, is unsuitable for the use of artillery or small arms. But this feature does not constitute a defect when it is otherwise employed, and thus we find that the department of military engineers, on discovering that their supply of mining powder was becoming rapidly exhausted, and being unwilling to draw upon the store reserved for the artillery, accepted a contract in the month of October, 1870, for a supply of chlorate powder wherewith to charge their torpedoes. This material answers admirably for this purpose, and would no doubt have been used in large quantities, had not a terrible accident occurred at the very commencement of its manufacture, which effectually put a stop to any further prosecution of it. About mid-day on the 6th of the above mentioned month a tremendous explosion threw into consternation the whole of the quarter of Grenelle, and completely shattered to pieces the premises of M. Deplazanet, a manufacturer of chemical products, situated in the Rue de Javel. Thirteen dead bodies and six wounded testified to the violence of the explosion. The cause was attributed, after a careful examination into the facts of the case, to a serious imprudence committed in the drying of the material. The powder which M. Deplazanet contracted to supply was composed of 2 parts of chlorate of potash, 1 part of prussiate of potash, and 1 part of powdered sugar, a mixture which had been long known as one which involves great danger in its preparation. What renders the occurrence the more to be deplored is that there was no absolute necessity for employing these ingredients, which were comparatively of a high price. The same end, so far as the effect of the powder was concerned, could have been attained by the use of other components. The proportion of chlorate of potash might have been reduced, and the sugar replaced by charcoal, without in the least impairing the practical value of the powder for mines and torpedoes. It is, however, of no consequence to discuss the matter, as the one explosion put an end to any further manufacture of the compound containing chlorate of potash. The next attempt was made shortly afterwards at Grenelle, and in this instance gun-cotton was the subject of trial. This substance is capable of being used in fire-arms, but not unconditionally. In order to make it available during the siege of Paris certain modifications and alterations must have been made in both the cannons and rifles, which were impracticable under the circumstances. The explosive was not intended to charge either cartridges on a small or large scale. The object was to fill shells with it, so as to economize as much as possible the ordinary powder; and there is no doubt, from the experiments undertaken, that hollow projectiles charged with it were exceedingly destructive in their effect. Although this attempt was of a far more promising character than its predecessor, it met with no better result. On the 27th of the same month that witnessed the former catastrophe a second explosion occurred, which destroyed the workshops at Grenelle, where the cotton was prepared. The cause of this accident was accurately traced, and found not to originate from any mismanagement or error in the preparation of the compound. A workman had gone upon the roof to solder some parts of it, and in some manner or other set it on fire. The damage in a pecuniary point of view was not great, but four persons were badly burnt. For the rest, the *coup de grace* was given to the manufacture of gun-cotton for the future.

The two substances that have been considered, that is, gun-cotton and gunpowder containing chlorate of potash, do not occupy the first rank in the scale of explosive compounds. This distinction belongs to others, such as nitro-glycerine, dynamite, picrate, and the cartridges of compressed cotton invented by Mr. Abel.* These cartridges are very little known in France, but during the year 1870 several experiments were conducted by the engineers of "Les Pons et Chaussées," which directs attention towards them. When used for blowing up walls and other obstacles they proved eminently successful. Their manufacture presents no more difficulty than that of the ordinary gun-cotcotton. The cartridges are formed of cotton prepared as usual and strongly compressed, and fired by means of a fulminating cap, which is exploded by either the electic spark or a safety fuze. As

* To these should be now added "Krebb's explosive," better known under its more familiar title of "lithofracteur."

considerable advantage would have resulted from possessing a supply of these cartridges, their manufacture was proposed to the Minister of War during the first week of the siege by a committee of engineers. The idea was at first adopted, but for various reasons was subsequently abandoned, and the whole proposition fell through. Passing on to the subject of picrates, their nature and properties have never been a question of any doubt. Many attempts have been made to utilize them for fire-arms, but their disruptive tendency has defeated all endeavors to so apply them. Their actual destructive effect is probably less than that of other explosives, although it is difficult to determine this in an accurate and conclusive manner. The only superiority they appear to possess is that of greater stability, but this is more than counterbalanced by the difficult character of their preparation. As an explosive compound of any value for warlike purposes, nitro-glycerine may be altogether omitted, since its preservation and transport are attended with dangers that few would be willing to incur. It might possibly be used were it manufactured on the spot.

The same disadvantages do not attend the somewhat similar compound dynamite, which may be regarded in some degree as nitro-glycerine solidified by its admixture with a porous description of sand, while at the same time it possesses an equal amount of explosive power. Although dynamite cannot be used in fire-arms, yet it might certainly serve for filling hollow projectiles. In order to ascertain this, experiments were conducted at Mont Valérian in presence of the Minister of Public Works, which succeeded in establishing the fact that shells filled with dynamite could be exploded with all the facility desired, but that there the merit of the explosive ended. It is well known that besides the mere explosion there are other conditions to be fulfilled before the proper effect of a shell is produced.

There are two principal conditions attached to the bursting of a shell, the fulfilment of which can alone insure its success in a destructive point of view; one is, that the shell should be shattered into as many fragments as possible, and the other that those fragments should be scattered in every direction to as great a distance as the charge will allow. The former of these conditions is fulfilled by the enormous tension of the gases which are developed at the moment of explosion, and the latter by the progressive action of the same gases. When this action is almost instantaneous, as happens in all explosives whose disruptive power is very great, the dynamical effect is little or none. The explosion itself may be terrific at the spot where it actually occurs, but there it ends. It does not travel to any distance. There is no question but that by the aid of dynamite, blocks of granite and metals can be shivered to pieces, upon which ordinary powder would produce no effect whatever ; but on the other hand, where substances which offer less solid resistance are to be operated on, a powder possessing an inferior degree of power is to be preferred. It is an error to imagine that it is always advantageous to employ in mines the most violent explosives. The explosive force of the compound should be proportional to the resistance to be overcome. It is thus readily perceived that dynamite would not answer so well as ordinary gunpowder in the case of mines intended to be sprung in such a manner as would destroy an enemy's works and overwhelm him with the *debris.* The one particular in which the incontestable superiority of this compound is apparent is that in which walls, gabions, entrenchments, and other obstacles are to be removed. In this respect it is unrivalled. A good deal has been stated respecting the value of dynamite as an agent for placing cannon *hors de service*, but opinions differ on this point. It must be borne in mind that the object aimed at is not so much the permanent destruction of the guns of an enemy as the rendering of them temporarily useless. Artillery which loads by the muzzle is "spiked" with a rapidity which cannot be surpassed, and those which are breech-loaders are equally readily rendered incapable of being fired by the breakage or abstraction of any of the movable parts of the breech. In any case it is far preferable to let a soldier carry a hammer with him into action than to encumber him with explosive materials, which are of no use to him as ammunition. From the "Transactions of l'Academie des Sciences," in which the results of some of the trials made with dynamite are recorded, it does not appear that very much has been done with it. With the exception of the attack on Buzenval, where it was employed to blow up the walls of a park, it has scarcely passed the experimental stage, and cannot be said to have reached the practical. The definite point arrived at is that a given effect can be produced with a comparatively small quantity of the material. It would, however, be forming a very unfair opinion of this powerful explosive were we to judge of its properties solely from the evidence afforded by the examples manufactured in Paris during the siege. The descriptions of dynamite prepared by the Prussians are very superior in quality. The French kinds contained a small proportion of nitro-glycerine, and the porous medium which was used, probably for want of something better, was not so well adapted for absorbing the explosive oil as the Kieselguhr, or silicious ingredient of M. Nobel. From the above remarks it is evident that the part played during the siege of Paris by what might be termed, in comparison with ordinary gunpowder, extraordinary explosives, was of little or no practical value, and consisted simply in blowing up some 20 persons engaged in their production, together with the premises in which they were manufactured.

We may now return to the powder manufactory of Philippe-Auguste, which, it had been decided, should be vigorously set to work directly the precise method of manufacture to be adopted had been determined upon. At present there are numerous processes existing for making gunpowder, and under ordinary circumstances each particular kind, whether cannon, mining, or sporting powder, is prepared by distinct varieties of machinery. Of late years it has been the custom to vary the manufacture of powder intended for war purposes accordingly as it is intended for ordnance or for small arms. In France the question has been raised whether powder intended for the heavy marine guns should not be prepared independently of the kind used for artillery, so that there would thus be three distinct kinds of gunpowder employed in warfare. Considering the conditions under which the establishment of Philippe-Auguste was erected, it is not to be expected that it could enlist in its service the aid of costly and elaborate machinery. It was, therefore, at once felt that the method of manufacture must be a simple process, easily manipulated, rapidly got into productive order, and answering all the actual requirements of the emergency. For these reasons the old method, as well as that of mills by which the powder for the Chassepot rifles and mitrailleuses was prepared, were excluded. The system of round barrels, used specially in the preparation of mining powder, might have been modified to suit, as its advantages were evident, so far as rapidity and economy were concerned. But it presented some difficulties with respect to the production of powder of a fine grain, which is indispensable to small arms. This objection was fatal to it, as the most urgent demand was for powder for the Chassepot rifles. For the same reason, powder prepared by agglomeration was rejected. Finally, M. Mauronard, who was appointed by the Minister of War the chief of the new establishment, adopted the method of "Formes et Presses." This was not a novel process, as it had been employed during the first revolution, when matters were pretty much in the same state. It then earned the name of the "revolutionary process," or the "Grenelle process," since it was at that place the first manufactory was erected. A violent explosion shortly afterwards destroyed not merely the whole of the manufacturing premises, but a large portion of the neighboring quarter as well. This part of Paris seems to have been a general victim to this kind of accidents. A full description of the method will be found in "L'Art de Fabriquer la Poudre-à-Canon," by MM. Botée et Riffault, and also in the "Guide Pratique de la Fabrication des Poudres," of Major Sterk. By utilizing some recent discoveries the old Grenelle process was rendered available for the production of powder during the recent siege of the French capital. The first step in the operation is to triturate separately the several ingredients, and to reduce them to the most complete state of subdivision, which was accomplished by the "Broyeurs cars." This was the first time the machine had been employed for powder, and unfortunately the only ones that could be obtained were originally adapted for the grinding of bones, or other substances infinitely more refractory than the components of gunpowder. Although the result cannot be stated to have been perfectly satisfactory, yet it was sufficiently so to warrant the expectation that the success would be perfect, when proper grinders or crushers were procured, adapted for the trituration of saltpetre, sulphur, and charcoal. The second phase of the process consists in the intimate mixture of the ingredients, after their thorough trituration, so as to render them completely incorporated. Instead of bringing at once the three ingredients into contact, the plan adopted in the preparation of mining powder was followed, namely, that of binary and ternary trituration, which allows of a more effectual admixture, with a corresponding diminution of danger. The compression of the substance, or the formation of the cake, which presents no features demanding especial notice, is the third part of the process.

There have been some improvements introduced recently into the manufacture of gunpowder which considerably simplify the loading and unloading of the presses. Instead of enclosing the powder in frames, it is placed in successive layers upon the plate of the press, each layer being separated as usual by a sheet of copper and a rag slightly wetted. The frames are thus abolished altogether. The proportion of water that should be mixed with the ingredients of powder is a very important element in its preparation. In the powder made at Paris during the siege this proportion was extremely small, and did not exceed above 4 per cent. This was not, however, a matter of choice, but of necessity. As there were no drying rooms nor apparatus, it was essential that as little water should be used as possible. The ingredients were nearly dry; the small quantity of moisture present, which was just sufficient for the formation of the cake, was driven out at the finish of the process. After leaving the presses the cake was first broken up by mallets, and the fragments transferred to the "Grenoirs-à-cylindre," above which were fixed sieves or strainers to separate the large grains from the powder. This cylindrical apparatus has been rarely used in France, and is no longer so now. The example put up on the premises at Phillippe-Auguste was taken from the English workshops, and gave very good results. The whole process terminates with the polishing of the powder, which operation not only polishes, but dries the grains as well. It is performed, as is well known, by placing the powder in a closed cask or barrel, and turning it about for a certain period, by which motion the grains acquire solidity and the consequent formation of dust is prevented. Some years ago a M. Laville, having remarked that in the course of the operation of polishing, the cask became appreciably heated, proposed to utilize the heat thus developed in drying the grains. For this purpose it is only necessary to employ a cask closed at one end and opened at the other, in such a manner as will allow the moisture to escape. This plan answers very well when there is but a small quantity of water mingled with the powder, as occurs in the case of sporting powder. It would be impossible to thoroughly dry powder by this operation, but even if it could be accomplished it is not needed. The powders that are the best dried invariably absorb about one per cent. of water on coming into contact with the atmosphere, so that there would be no advantage derived in pushing the process to a complete desiccation. The powder made in Paris at the time we write of was dried in the polishing casks, and it now remains to mention the tests applied, in order to arrive at a correct estimate of the value of it when applied to the purposes of warfare. Gunpowder made with saltpetre is not endowed with the great disruptive force of that into the composition of which chlorate of potash enters, and therefore the two principal qualities to which attention must be directed are cleanliness and durability. In other words, it must not foul the gun, and it must be easily kept in a state of good preservation and efficiency. The latter consideration may be neglected in instances similar to the one under notice, where but a short period intervened between the manufacture of the article and its subsequent consumption. Cleanliness, or the property of non-fouling, is an indispensable one in all powders intended to be used in small arms. In fact, the old description of gunpowder could not be employed in the breech-loading rifles of the present day. The new powder was tried by firing 100 consecutive rounds with the same Chassepot, and was found to behave equally well as the ordinary mill powders. The strength was tested by means of the ballistic pendulum, upon which a Chassepot was mounted. The initial velocity of the ball, with a charge of 89.5 grains of powder, was 1,250 ft. per sec., while that produced with the ordinary powder under similar conditions was 1,390 ft. per sec. The difference was not sufficient to indicate any great inferiority in the new preparation, or to render it unsuitable for using in rifles and artillery. Moreover, as the density of the Phillippe-Auguste powder was greater than what there was any necessity for, the initial velocity of the ball could be increased by diminishing it and making the grain finer. On the whole, the attempt was decidedly successful—so much so that the question will be asked, why this mode of manufacture could not be universally employed, since it is much simpler and more rapid than the methods usually adopted for the preparation of the same material. In order to give a satisfactory reply to this question, the behavior of the powder with other weapons than the Chassepot must be taken into account, such as rifles loading at the muzzle, and also smooth-bore guns. The difference at once becomes manifest. The initial velocity of the ball decreases in the muzzle-loading rifle, and becomes very much reduced in the smooth-bore. The explanation of these facts is simple. The initial velocity of the ball depends, according to the nature of the weapon with which it is fired, upon the absolute strength of the powder, and its "vivacity." The first of these will to a great extent suffice for rifles similar to the Chassepot, in which the ball is completely forced into the grooves of the bores, in consequence of the loading taking place at the breech. But in rifles which load at the muzzle the ball is only partially compressed in this manner, and the vivacity of the charge comes into play. This attains its maximum in the smooth-bore gun when there is no compression whatever, and consequently a good deal of windage. Thus the powder prepared by casks and presses, although suitable for needle-guns, would only answer indifferently well for arms of another description, especially fowling-pieces. Gunpowder manufactured by the usual processes have in these instances an incontestable superiority. Apart from all other considerations, the great merit of the undertaking commenced in the premises of Phillippe-Auguste was undoubtedly the power of manufacturing in so short a period any gunpowder which should have been of real service to the besiegers. The daily production at first amounted to between 2 and 3 tons, and afterwards reached between 5 and 6. Had circumstances required it, a greater quantity could have been provided. We trust that the necessity for establishing a powder manufactory in the heart of Paris may never again occur.

DEPHOSPHORIZING IRON ORE.

From "Engineering."

Metallurgists have for a long time past made great efforts to utilize iron ores which are contaminated by phosphorus, and which in consequence yield an iron of inferior quality, it being almost invariably cold-short. The quantity of iron ore so contaminated is enormous in many of the more recent geological formations, such as the oolitic, cretaceous, and tertiary formations, where the ore is either found in the shape of a carbonate or a hydrate of iron, always intimately contaminated by phosphate of lime. Of this character are the heavy beds of iron ore in the Middlesbrough district, in Luxembourg, Lothringen, Bavaria, Hanover, Bohemia, and many other localities. It was the phosphorus which forbade the use of a number of these ores for many years, until modern metallurgists had learnt, by using larger furnaces and more limestone, and by adopting a judicious admixture of other ores, to extract a cheap and tolerable iron from them. Nevertheless, it has always been a desideratum to neutralize the injurious influence of the phosphorus in one way or the other. Some engineers have endeavored to extract the phosphorus from the ore, wherein it is contained in the shape of basic phosphate of lime, which is insoluble in water, and the object of all their exertions being to render this compound soluble by converting it into acid phosphate of lime by the action of other mineral acids, which would combine with a part of the lime, and set an equivalent of phosphoric acid free to combine with the rest of the phosphate of lime, thus forming a superphosphate. This idea is stated to have been lately successfully carried out by T. Jacobi, of Adalberthütte at Kladno, near Prague, by exposing the ore to a solution of sulphureous acid in water, or to the simultaneous action of sulphureous vapors and cold water, when this acid forms a soluble compound with the lime, and at the same time converts the rest of the phosphate to the soluble form, so that it can be washed away with cold water. The inventor exhibited his process during the last meeting of the Association of German Engineers and Architects, at Prague, on November 3d, 1871. The samples of fibrous and fine-grain bar iron and puddled steel made from such dephosphorized ore, and produced to the Association, were of an excellent character, and found unanimous approval. The sulphureous gas is either produced by burning sulphur or by the calcination of pyrites or other minerals containing sulphur. The same end has been attained by another engineer, B. Osann, of Potsdam, by employing in a similar way diluted hydrochloric acid, which is obtained very cheaply in quite a novel mode. At the above mentioned rock salt mines of Stassfurt and Leopoldshall, large masses of chloride of magnesium are obtained, together with the salts of potassium, and are thrown away as valueless. Now, if this chloride of magnesium, which contains always a considerable amount of water, be heated to about 110 deg. Cent. or 230 deg. Fahr., it gives up so much water as to form a trihydrated salt of chloride of magnesium, and if this is rapidly heated to the melting point of lead it is decomposed, giving up vapors of hydrochloric acid, when hydrate of magnesia is left as residue in the retort. The hydrochloric vapor acts exactly as was described of the sulphureous acid. Both of the processes above described are worthy of attention ; but the information we have received concerning them is not as yet sufficiently detailed to enable us to form any decided opinion regarding their practical merits.

Other metallurgists have sought to get rid of the phosphorus during the puddling of the iron, or even just before, when the pig iron runs from the taphole in the moulds. For removing the phosphorus during the operation of puddling, Director Spamer, at Ilsederhütte, in Hanover, adds to each heat of 500 lbs. of pig iron about 6 lbs. of fluoride of calcium (fluorspar), which readily melts when brought in contact with the iron, so that it can be intimately mixed with it, when the fluorine combines with the silicon of the iron to fluor silicon, and phosphoric acid is absorbed by the lime and carried into the tap cinder, or finely powdered fluorspar is thrown into the iron-moulds before they are filled with liquid iron when tapping the blast furnace. In both instances the result obtained is said to be excellent, the cold-shortedness of the bar iron having entirely disappeared. This appears to be a modification of the Henderson process, which has lately attracted much attention in America.

ON JOURNAL FRICTION IN STEAM ENGINES.

By W. J. MACQUORN RANKINE, C.E., LL.D., F.R.S.

From "The Engineer."

(1) Object of this Communication.—The object of this communication is not to publish any new research or original theory, but to set forth and illustrate in a simple manner some elementary principles relating to a subject in which, though it has long been familiar to engineers, their practice sometimes differs widely—that of the construction of steam engines, and especially of marine steam engines, so as to diminish the work wasted in overcoming the friction of the shaft journals. It is well known that in engines with more than 1 cylinder the efforts exerted through the piston-rods on the cranks, and thence transmitted to the bearings of the shaft, may be made to a greater or less extent to balance each other, thus diminishing friction and promoting economy of power; and that the balance of efforts, and consequent economy of power and of fuel, may be in many cases improved by increasing the number of cylinders. Against this advantage have to be set the additional

complexity, and consequent additional cost, of an engine with an increased number of cylinders. It is obvious that no rule of universal application can be laid down as to whether the preference is to be given to fewer cylinders and greater journal friction, or to more cylinders and less journal friction; but that each case must be decided according to its own special circumstances to the best of the judgment of the engineer. The application of that judgment may be facilitated by showing the results to be expected in a set of examples, such as those contained in the sequel of the present paper.

(2) Friction at Crank Journals.—The proportion which the work lost in overcoming friction at a single crank journal bears to the whole work done in driving the crank, is the product of the following factors:—First, the ratio in which the mean pressure at the bearing surface of the journal exceeds the mean effort exerted by the piston on the crank. This ratio is very nearly equal to the mean value of the secant of the angle of obliquity of the connecting rod to the piston-rod, and is unity plus a small fraction, unless the obliquity is great. Secondly, the ratio in which the friction is less than the bearing pressure; in other words, the coefficient of friction. This may be taken as ranging from .04 to .08, according to the smoothness and state of lubrication of the bearing surfaces. Thirdly, the ratio in which the distance through which the friction has to be overcome at each revolution is less than the distance through which the effort is exerted; in other words, the ratio in which the circumference of the journal is less than twice the stroke of the piston. So long as the 3 factors are the same the product is the same: that is, the fraction of the whole work of the engine which is wasted in overcoming the friction of crank journals is the same, whether the work is done in 1 cylinder or in several, provided the coefficient of friction, the mean obliquity of the connecting rods, and the proportion borne by the diameter of a crank journal to the stroke are unaltered. In the examples chosen for illustration it will be assumed that those quantities are unaltered: that assumption simplifies the calculations, and does not affect to any important extent the accuracy of the conclusions arrived at. The loss of work through friction at crank journals may be taken as not sensibly affected in practice by the greater or less number of cylinders of which the engine is made up.

(3) Friction of Shaft Journals.—The part of the work wasted in overcoming friction, which is capable of diminution by means of a suitable distribution of power amongst two or more cylinders, is that which is expended at the bearings of the shaft journals. The principles according to which such diminution may be effected depend upon the difference between the resultant of a set of forces and what may be called their aggregate. The aggregate of a set of forces is the sum of their magnitudes, in the arithmetical sense of the word sum; that is, the quantity obtained by adding these magnitudes together, regarding them all as positive. The aggregate of a set of forces is only equal to their resultant, when all the forces act in the same direction. In every other case the aggregate is greater than the resultant. For example, when a pair of equal and opposite forces either balance each other, or form a couple, their resultant force is nothing; their aggregate has twice the magnitude of each of them. When two forces act through one point in different directions their resultant is represented by the diagonal of a parallelogram; their aggregate, by the sum of the two sides, which is always greater than the diagonal. Hence it is obvious that two sets of forces may have equal resultants, but very different aggregates. Supposing, as is always the case in marine engines, that the pressure or reaction due to the resistance overcome is borne by special bearings for that purpose (such as paddle shaft journals, and propeller shaft journals), it follows from the principles of dynamics that the mean value of the resultant of the pressures at the engine shaft journals is equal and opposite to the mean value of the resultant of the pressures at the crank journals, combined with the weight of the shaft; but the aggregates of those two sets of pressures may differ in any proportion. When several pressures act at once upon one bearing, the total friction is that due to their resultant, and is the same as if the several pressures were replaced by one pressure equal to their resultant. But when several pressures are applied, each to a different bearing, the total friction is that due to their

aggregate, which cannot be less than their resultant, and may be greater.

(4) Comparison of Crank Journal Friction and Shaft Journal Friction.—Assuming the coefficient of friction to be the same (as it really is with smooth surfaces and good lubrication) for the crank journals and for the engine shaft journals, the ratio which the work wasted at the shaft journal bears to the work wasted at the crank journals is the product of the following factors. First, the ratio which the diameter of the shaft journals bears to the diameter of the crank journals; a ratio which seldom differs much from that of equality. Secondly, the mean value of the ratio which the aggregate of the pressures at the engine shaft journals bears to the aggregate of the pressures at the crank journals. The economy of power, so far as it arises from the diminution of friction at the shaft journals, mainly depends upon so designing the engine as to make this second factor as small as possible; and for practical purposes, indeed, we may regard its smallness as a measure of the comparative economy of frictional work in different engines, so far as that work is done against journal friction.

(5) Principles of the Determination of Comparative Economy in Journal Friction.—The process of determining the ratio already referred to, which the mean value of the aggregate of pressures at the shaft journals bears to the aggregate of pressures at the crank journals, involves two steps. First, the finding of the mean value of the ratio that the resultant force of the pressures at the crank journals bears to the aggregate of those pressures, and also the arm of the resultant moment of those pressures relatively to an axis transverse to the axis of rotation; that resultant force and resultant moment being, in other words, the tendencies of the pressures at the crank journals to shift the shaft parallel to itself, and to alter its direction respectively; and, secondly, the finding of the pressures at the shaft journals in terms of that resultant force and resultant moment, and of the weight of the shaft.

These processes are to be performed for the various parts of a revolution in which they give different results; and from those results a mean value of the required ratio is to be deduced.

During the second process the effect of the weight of the shaft may in many cases be neglected, provided the pressures due to its action alone are less than those due to the vertical component of the resultant of the pressures at the crank journals; for then the weight diminishes the pressures at the shaft journals as much during one-half of each revolution as it increases them during the other half, or nearly so; so that its influence on the mean value of the pressures at the shaft journals vanishes or becomes insensible. The weight of the shaft may be neglected also, in every case in which it is very small, compared with the resultant of the pressures at the crank journals. On the other hand, when the pressures at the crank journals are so adjusted as to make the pressures at the shaft journals due to their actions, either nearly vertical, and less than those due to the weight of the shaft alone, or very much less than those latter pressures, and in any direction, the mean aggregate pressure at the shaft journals is very nearly equal to the weight of the shaft simply; and this realizes the highest practicable economy in the journal friction of steam-engines.

(6) Formulæ.—To find the aggregate of the pressures on the crank journals, the thrusts or pulls along the connecting rods are simply to be added together. To find the resultant of those pressures and its moments, let P be one of them, i the angle which it makes with a line pointing vertically downwards, Y its horizontal component, Z its vertical component, positive downwards. Then $Y = P \sin. i$, and $Z = P \cos. i$, observing that cosines of obtuse angles are negative. The horizontal and vertical components of the required resultant are respectively ΣY and ΣZ (Σ denoting algebraical summation, in which positive and negative quantities are distinguished). Let R denote the resultant, then

$$R = \sqrt{\{(\Sigma Y)^2 + (\Sigma Z)^2\}}$$

For a rough approximation, such as is in general sufficient in treating the questions to which this paper relates, the obliquity of each connecting rod to its piston-rod may be neglected, so that instead of putting for the angle i the varying angle made by the connecting rod with the vertical, we may put the constant angle made by the piston-rod with the vertical, or, in oscillating engines, the mean value of that angle. To find the resultant moments, let the axis of rotation be that of x: assume a convenient point in that axis for the origin of co-ordinates—in general, a point midway between the centres of the two shaft bearings is the most convenient. Conceive two transverse axes perpendicular to the axis of x, to traverse the origin; the axis of y horizontally, and the axis of z vertically. Let x denote the distance of one of the forces P from the plane of y and z the moment of that force about the axis of y is x Z, and about the axis of z, x Y; the resultant moments of the pressures about those axes are respectively Σx Z and Σx Y. To find the pressures at the shaft bearings due to the pressures at the crank bearings, irrespectively of the weight of the shaft, let the origin be supposed to be midway between the bearings, and let 2 b be their distance from centre to centre. Let V and V^1 be the vertical pressures, and H and H^1 the horizontal pressures at the two bearings respectively. Then for the bearing at the positive side of the origin we have

$$V = \tfrac{1}{2} \Sigma Z + \frac{\Sigma x Z}{2 b};$$

$$H = \tfrac{1}{2} \Sigma Y + \frac{\Sigma x Y}{2 b};$$

and for the bearings at the negative side of the origin

$$V^1 = \tfrac{1}{2} \Sigma Z - \frac{\Sigma x Z}{2 b};$$

$$H^1 = \tfrac{1}{2} \Sigma Z - \frac{\Sigma x Y}{2 b}.$$

The resultant pressures are respectively

$$\sqrt{(V^2 + H^2)} \text{ and } \sqrt{V^{1\,2} + H^{1\,2})};$$

and their aggregate is

$$A = \sqrt{(V^2 + H^2)} + \sqrt{(V^{1\,2} + H^{1\,2})}.$$

Each of the pressures denoted by P is a more or less variable quantity, and even when its variations of magnitude are neglected (as is the case in the following examples) its direction is reversed in each half revolution; so that in using algebra the components of P change from positive to negative. Separate calculations are to be made of the aggregate pressure A for each part of a revolution in which the changes of P cause A to have a different value; each value of A is to be multiplied by the fraction of a revolution during which it exists; then the products, being added together, will give the mean value of the aggregate pressure, neglecting the weight of the shaft. To take the weight of the shaft into account, divide it into two parts, inversely proportional to the distances of the centres of the two bearings from the centre of gravity of the shaft, and let W and W^1 be those parts. Then in the expressions for the pressures at the bearings $V + W)^2$ and $(V^1 + W^1)^2$ are to be put instead of V^2 and $V^{1\,2}$ respectively. The quantities in brackets are sums when V and V^1 are positive, that is, downward; and differences when V and V^1 are negative, that is, upward; and the change from positive to negative takes place at each half revolution; so that in taking the mean value of the aggregate pressure for every term in which the quantities in brackets are sums, there is a corresponding term in which they are differences. The consequence is that whichever of the quantities V and W, or V^1 and W^1, is small compared with the other, and in many cases, whichever is simply the smaller of the two, has a small or an insensible effect on the mean aggregate pressure, as has been already stated.

7. Examples.—The following examples are confined to very simple cases, being those which most commonly occur in practice. They consist of calculations whose results express values of the ratio borne by the aggregate pressures on the shaft journals to the aggregate pressures on the crank journals, which ratio, as already stated, expresses the ratio of shaft journal friction to crank journal friction, if the diameters of the journals and the coefficients of friction are the same. For brevity's sake, this ratio will be called comparative shaft friction. The weight of the shaft will be neglected, for the reasons formerly stated, except where the pressures at the shaft bearings, due to the forces at the crank bearings, vanish; when the shaft friction is that due simply to the weight of the shaft.

Case I.—One crank; one piston; crank between the two shaft bearings. Comparative shaft friction=1.

Case II.—One crank; one piston; crank beyond the two shaft bearings. Let $2b$ be the distance between the centres of the bearings; x, the distance of the centre of the crank bearing from a point midway between the shaft bearings, which in this case is greater than b; then if P be the pressure at the crank bearing, the pressures at the shaft bearings are respectively

$$-\frac{P}{2}\left(\frac{x}{b}-1\right) \text{ and } +\frac{P}{2}\left(\frac{x}{b}+1\right)$$

and their aggregate is $P\frac{x}{b}$; so that we have comparative shaft friction $=\frac{x}{b}$. This ratio is greater than unity; showing the disadvantage in economy of power which arises from having the crank overhanging the shaft bearings.

CASE III.—One crank between the shaft bearings; 2 pistons, with rods at right angles. The efforts exerted by the 2 pistons being each = P, their aggregate is 2 P; their resultant is $P\sqrt{2}$; and consequently comparative shaft friction $=\frac{\sqrt{2}}{2}=.707$ nearly. This is a frequent arrangement in marine engines.

CASE IV.—One crank, between the shaft bearings; 3 pistons with rods making equal angles of 120 deg. The aggregate of the efforts exerted by the 3 pistons, is 3 P; their resultant is 2 P, and consequently comparative shaft friction $=\frac{2}{3}=$ .667 nearly. This is the arrangement of some paddle wheel engines.

CASE V.—One crank between the shaft bearings; a great many pistons, with rods making equal angles. Comparative shaft friction, as the number of pistons is increased, approximates to the limit $\frac{2}{\pi}=.637$ nearly; and this is the limit of the extent to which it is possible to diminish that ratio, when only one crank is used.

In the next class of cases there are supposed to be 2 cranks at equal distances, denoted by $\pm c$, from a point midway between the shaft bearings, whose distance apart from centre to centre is $2b$; and as before, the efforts exerted by the pistons are supposed to be equal. The shaft is further supposed to have no intermediate bearings between the cranks, or to exert no appreciable pressure on those bearings.

CASE VI.—Two cranks, making with each other an angle equal to the fraction n of a half revolution; 2 pistons, the rods parallel to each other. Aggregate of pressures at crank journals 2 P. In this case, during the fraction n of each half revolution, the efforts of the pistons are opposite; their resultant force is nothing; their resultant moment is $2Pc$, and the aggregate pressure at the shaft journals $\frac{2Pc}{b}$. During the remaining fraction $1-n$ of each half revolution the efforts of the pistons are parallel and in the same direction; their resultant force is 2 P; their resultant moment is nothing; and the aggregate pressure at the shaft journals is 2 P. Hence the comparative shaft friction is

$$n\frac{c}{b}+1-n.$$

The following are particular examples:

	Comparative shaft friction. Any value of $\frac{c}{b}$	$\frac{c}{b}=\frac{1}{2}$
(1) $n=\frac{1}{2}$, that is, cranks at right angles..........	$\frac{1}{2}\frac{c}{b}+\frac{1}{2}$	.... $\frac{3}{4}=.75$
(2) $n=\frac{3}{4}$, that is, cranks at 135 deg. apart........	$\frac{3}{4}\frac{c}{s}+\frac{1}{4}$	.... $\frac{5}{8}=.625$
(3) $n=1$, that is, cranks opposite in direction...	$\frac{c}{b}$	.... $\frac{1}{2}=.500$

The first of these particular examples is the commonest of all arrangements of 2 cylinders comprehending ordinary pairs of single-cylindered engines, and the form of compound engine introduced by Nicholson, and improved by Cowper, when the distribution of the steam is such as to make the efforts on the two pistons equal. The second is an example of an arrangement used in some two-cylindered expansive engines, such as the later form of Craddock's, and Carrett and Marshall's, in order to have the motions of the pistons nearly contrary, and at the same time to have the power of turning the centre. The third is that form of compound engine which, when the efforts of the two pistons are equal, realizes the greatest economy in shaft friction possible with two cylinders only. It is deficient in the power of turning the centre, so that in steam vessels it is advisable to use such engines in pairs.

CASE VII.—Two cranks, between the shaft bearings, opposite in direction; 4 pistons, each crank driven by two piston rods at right angles to each other. The solution of this case is obtained by combining those of case III., and of the third example of case VI., that is to say, comparative shaft friction $=\sqrt{\frac{2}{2}}-\frac{c}{b}$. This is nearly the arrangement in some pairs of compound marine engines, made by Messrs. Randolph, Elder & Co. The pairs of piston rods are not in every case exactly at right angles; to allow for this, let the angle which they make with each other be $n^1\pi$, being the fraction n^1 of a half revolution; then for the preceding expression substitute the following:

$$\frac{c}{2b}\left\{n^2\sqrt{(2-2\cos. n^1\pi)}+(1-n^1)\sqrt{2+(2\cos. n^1\pi)}\right\}$$

The result, when $n^1\pi$ is an oblique angle, is greater than when it is a right angle, but the difference for small obliquities is unimportant in practice.

Case VIII.—Three cranks, making equal angles of 120 deg.; 2 shaft bearings only with sensible pressure at the distance apart, b; the middle crank midway between the bearings; the other two at equal distances $\pm c$ from it, 3 pistons, with parallel rods. The aggregate of the pressures at the crank bearings being 3.P, their resultant force is at all times $=$ P. The resultant moment is nothing when the two outer cranks are at the same side of the shaft, and 2 P c when they are at contrary sides, the latter being the case during two-thirds of each half revolution. The pressure at a given bearing has in the three successive thirds of each half revolution the three values

$$\tfrac{1}{2}\text{P} - \text{P}\frac{c}{b};\ \tfrac{1}{2}\text{P};\ \text{and}\ \tfrac{1}{2}\text{P}+\text{P}\frac{c}{b}.$$

The aggregate of these pressures has one or other of the following values, according as $\frac{c}{b}$ is less or greater than $\frac{1}{2}$. If $\frac{c}{b}$ is less than $\frac{1}{2}$, P. If $\frac{c}{b}$ is greater than $\frac{1}{2}$, 2 P $\frac{c}{b}$ for two-thirds of each half revolution, and P for the remaining third. Hence we have for the comparative shaft friction:

If $\frac{c}{b}$ is less than $\frac{1}{2}$; $\frac{1}{3}=.333$ nearly.

If $\frac{c}{b}$ is greater than one-half $\dfrac{4\frac{c}{b}+1}{9}$

This arrangement of cranks occurs in the 3-cylindered engines of Messrs. Maudslay; but as there are intermediate bearings between the cranks, the calculated result will not be realized unless the pressures at these bearings are insensible.

Case IX.—Three cranks between 2 shaft bearings; the 2 outer cranks opposite in direction to the middle crank; the 3 piston rods parallel; the efforts of the 2 outer pistons each equal to one-half of the efforts of the middle piston. Here there is a balance of efforts at all times, the resultant force and the resultant moment being each sensibly equal to nothing. The shaft friction is simply that due to the weight of the shaft. This arrangement realizes the greatest possible economy of power in the friction of the shaft journals. It was the invention of the late John Elder, who used it in compound expansive engines with the high-pressure cylinder in the middle, and a pair of low-pressure cylinders, one at each side. In order to turn the centre and give uniformity of action, he combined those 3-cylinder engines in pairs, with piston rods at right angles, acting on one set of 3 cranks, so that there were 6 cylinders in all. Such was the construction of the engines designed by Elder for H. M. S. Constance; and upon trial they showed an economy of power, over and above that due to expansion, which can be accounted for only by the smallness of the journal friction.

8. Remarks.—It appears from the preceding examples that various degrees of economy in the friction of the engine shaft journals may be attained by means of suitable forms of engine; the higher degrees of economy requiring more numerous cylinders, and consequently greater cost and the highest possible degree, 3 cylinders for a single engine, and 6 for a pair of engines. It may not be always advisable to increase the number of cylinders for the sole purpose of diminishing friction; but when, for other objects, such as high rates of expansion, many cylinders are used, it is very important to know how to arrange them so that they may, by the balance of efforts of the pistons, realize the greatest economy of friction consistent with their number.

W. J. M. R.

Sassafras-oil.—In Richmond, Va., a firm of colored persons has for 2 years manufactured sassafras-oil on a large scale. The root is purchased at the factory at the rate of 30 cents per 100 lbs., and 40,000 lbs. are used per week, producing two per cent., or 800 lbs. of unrectified oil. The oil is used for scenting toilet-soaps, flavoring tobacco, etc.

EXPERIMENTS ON THE STRENGTH OF MATERIALS.

From "The Builder."

A variety of experiments on the strength of materials, were made by Mr. Kirkaldy for the works of the new bridge at Blackfriars, and were referred to by Mr. Carr, in his paper. Some of these experiments gave results as follows :

Bricks, in Piers Four Courses High.

Description of Bricks.	Size of Pier in Bricks.	Mortar.	Failing slightly. Tons per foot super.	Entirely crushed. Tons per foot super.
Common stock recessed	1½ by 1½	Lias lime	17	27
Ditto ditto	1½ by 1½	Ditto	21	30
Red Bricks, machine-made	1½ by 1½	Ditto	20	40
Ditto hand-made	1½ by 1½	Ditto	20	36
Galt	1½ by 1½	Roman cement	24	59
Ditto	1 by 1	Ditto	54	72
Clark's Sudbury machine	1 by 1	Portland	49	76
Uxbridge red, hand-made	1 by 1	Ditto	44	53

Stone Cubes of Two Inches bedded on Sheet Lead.

Description.	Failing slightly. Tons per foot super.	Entirely crushed. Tons per foot super.
De Lank granite, Cornish	283	363
Ditto ditto	279	....
Ditto ditto	349	377
Guernsey	276	830
Ditto	761	1,150
Cheesewring, Cornish	295	403
Ditto ditto	194	322
Portland	106	155

A small polished column of red Mull granite, length 6 in., diameter nearly 3 in., was cut through the middle, and the cut faces accurately ground; when tested packings of pine were placed at each end, and the surfaces, where cut in two, were put together with a little boiled oil. This 3-in. column bore a strain of 60 tons, or 8¾ tons per sq. in., 1,260 tons per sq. ft., or the weight of a column 16,380 ft. high.

An experiment was made to test the effect of a small area of iron pressing on a surface of De Lank granite. A cube of 1-in. wrought iron was placed between 2 blocks of granite, 6 in. by 6 in. by 5 in.; a packing of ¼ in. of pine was placed between the granite and the machine, and between the iron cube and granite. One of the blocks was split with a pressure of 50 tons; the block which was not injured was again submitted to pressure with another cube ; it was then fractured with a pressure of 52 tons. The iron cubes were reduced in thickness $\frac{1}{6}$, with an equivalent lateral extension.

It was desired to see what would be the effect of great pressure on the skewback stones. A stone was worked ¼ scale, and a corresponding portion of arch rib made; the two were bedded together with lead run in between, in the same manner as proposed for the arches themselves. They were then gradually submitted to a pressure of 200 tons, but without any effect except extrusion of the lead ; the iron, however, with 18 tons per inch, seemed to have quite as much as it could carry. Being all to ¼ scale, the area under pressure was $\frac{1}{16}$ the real size ; the pressure was therefore equivalent to 3,200 tons in the bridge itself, the actual pressure in work being under 400 tons.

Gun-metal cramps were also tested, the result being the rejection of several mixtures of metal submitted by the contractors, and an increase of strength obtained from 17,519 lbs. per in. area to 28,883 lbs. (7¾ to nearly 13 tons).

In order to test the strength of timber used as struts, 2 whole balk, 20 ft. in length and 13 in. square, were submitted to end compression. The red timber crippled with 138 tons, or 112 tons per ft. area, and the white with 147 tons, or 126 tons per foot area, the reduction in length being in one case ⅝ in., in the other ½ in.

Specimens of the fractures are now exhibited.

Portland cement was also tested, the standard of the Metropolitan Board of Works being adopted, 110 lbs. weight per bushel, and 500 lbs. tensile power on $2\frac{1}{4}$ in. area; some results obtained were as high as 733 lbs. on the $2\frac{1}{4}$ in.

Experiments were made on the iron from time to time, but the specified strength was not fully attained; it was, perhaps, pitched rather too high for such work. The extension of $\frac{1}{625}$ part of the length was given by strains varying from 13 tons to 15 tons instead of 16 tons, but even with this, the elastic limit is just about 4 times the working load, which is ample allowance for safety, taking into account a very large deterioration from time and corrosion.

The above figures are stated in round numbers. The results, as given by Mr. Kirkaldy, are in every respect most accurate and minute, but high numbers of pounds instead of tons, and long decimals, are not suitable for such a sketch as this.

EXPLOSIVE COMPOUNDS.

From "Engineering."

DYNAMITE AND ITS MANUFACTURE.

Having in previous articles considered the progress made during the past 5 years in gunpowder and gun-cotton, we have in the next place to notice dynamite, one of the most formidable, and at one time one of the most promising, rivals of gunpowder for special purposes. The base of dynamite is nitro-glycerine, which ranks amongst the remarkable materials employed to replace gunpowder as destructive agents. It was discovered by Sobrero in 1847, and is produced by adding glycerine in successive small quantities to a mixture of 1 volume of nitric acid of sp. gr. 1.43, and 2 volumes of sulphuric acid of sp. gr. 1.83. The acid is cooled artificially during the addition of the glycerine and the mixture is afterwards poured into water, when an amber colored fluid separates from it. This fluid is insoluble in water, possesses no odor, but has a sweet pungent flavor and is very poisonous, a minute portion placed on the tongue producing a violent headache. The liquid has a specific gravity of 1.6, and solidifies at 5 deg. C. or 40 deg. Fahr. The properties of nitro-glycerine are tolerably well known; it simply burns when flame is applied; if paper be saturated with it and struck sharply a somewhat violent detonation is produced. In 1864 Mr. Alfred Nobel, a Swedish engineer, applied nitro-glycerine to the purposes of blasting. He first used gunpowder saturated with nitro-glycerine, which burned more brightly in the open air than unsaturated gunpowder, but its destructive effect under confinement was from 4 to 6 times that of pure powder. The oil itself cannot be exploded by an ordinary fuze, so Mr. Nobel attached a small charge of gunpowder to the end of the fuze and by this means the explosion of the nitro-glycerine was effected.

But although a very useful agent, nitro-glycerine often proved itself a highly dangerous one. The frequent and fatal accidents which occurred with it between the date of its practical application and the year 1868, will doubtless be fresh in the memory of our readers. On the 3d of April, 1866, the West India Company's steamer, European, whilst unloading at Aspinwall, had her decks ripped up and her sides blown out, whilst a wharf 400 ft. long was literally torn to pieces, about 50 persons being killed and a number wounded, by an explosion of nitro-glycerine on board the vessel. On the 16th of the same month, 2 cases of the oil arrived at San Francisco by the Pacific mail steamer and were taken into that city, where they were no sooner deposited than they exploded, the results proving terribly fatal to human life. In Sydney, New South Wales, too, about the same time, 2 packages of the oil exploded in a store in Bridge street, with disastrous results, whilst at home later still we have had two fatal explosions, one at Cwm-y-glo, near Carnarvon, and the other in the suburbs of Newcastle. Two other cases of explosion occur to us; one in which a carman greased the wheels of his cart with nitro-glycerine, and the other where the nitro glycerine was frozen, and the workmen placed lumps of it on a stove to thaw. The cause of the explosions was here very apparent, as it also was in the case of the Cwm-y-glo accident, where the packages of nitro-glycerine were being carted to the slate quarries, a package having been placed loosely on the front-board of one of the carts. This package doubtless fell off the cart, and, exploding, caused the explosion of the remainder of the packages. Although there is no proof of the manner in which the other accidents were actually caused, it is tolerably certain that a blow must have been in some way or other administered to the cases containing the oil. Therefore, since nitro-glycerine has been largely used in the past with a comparatively small number of accidents, and since its manufacture is still carried on upon a large scale for conversion into dynamite, it is only fair to assume that with reasonable care in manipulation, accidents with nitro-glycerine would not occur.

The accidents, however, which resulted from the use of nitro-glycerine, led Mr. Nobel to experiment with the material in various ways with the view of rendering it less dangerous. The first result was the discovery that it could be rendered non-explosive, either from percussion or heat, by mixing with it methylic alcohol. When required for use, water was added, which absorbed the spirit and allowed the oil to sink to the bottom of the vessel, whence it was drawn off for use, its explosive nature being restored. This method of protecting the treacherous oil was adopted to some extent; it answered the purpose during storage or transit, but, at the time of use, all the dangerous properties of the oil were present, and accidents arising from carelessness continued to occur. Mr. Nobel, satisfied that the protective arrangement was only half a solution of the difficulty, continued his researches, and early in 1868, he succeeded in effecting a new combination in which nitro-glycerine was rendered perfectly innocuous except under the actual conditions of work. This desirable end was attained by mixing the oil with silica—fine gravel for instance—the compound resembling in appearance course brown sugar, a little damp. To this substance Mr. Nobel gave the expressive name of "dynamite," and with it he made a series of experiments at the Merstham Greystone Lime Works, in July, 1868. The object of these experiments was to illustrate the safe and harmless character of dynamite under any other conditions save those of actual work, and to demonstrate its resistless energy when fired by a percussion fuze. The experiments were thoroughly successful, and proved beyond a doubt that dynamite could not be exploded by concussion, and that if placed on a fire or ignited in the ordinary way, it only burned slowly out. When, however it was fired by a percussion fuze, even in the open air, all its intensity of power was fully developed, and was increased by exploding it in water or under conditions of confinement.

The most severe tests for safety failed to show that any danger was present in this material, whilst, on the other hand, there was no condition under which its violence was not fully developed when fired with a detonating fuze. One out of many illustrations of its power is worthy of notice here. A cylindrical block of wrought iron, 12½ in. high and 10½ in. in diameter, and having a 1 in. hole bored through its centre, was used. The bore hole was lightly filled with dynamite and fired by a time fuze, the charge not being plugged. The explosion split the cylinder in two equal halves longitudinally to the axis of the bore, one-half being bedded in a grass bank 80 ft. away from the place where the charge was fired, and the other half being found about 50 ft. in an opposite direction, having been stopped by a mass of limestone rock. The iron showed a clean split, the bore-hole being enlarged to 1¾ in. at the centre, showing the enormous compression the metal had undergone at that point. A charge wrapped in thin paper and fired under water exhibited the same resistless power, and demonstrated the fact that dynamite is unaffected by moisture. The only point of doubt that arose in our mind at the time of witnessing the experiments, was as to whether any mechanical separation of the silica from the oil or chemical change in the compound could occur in the course of time which would render dynamite as dangerous as nitro-glycerine. Mr. Nobel, however, stated that there was no fear of such an occurrenee, inasmuch as he had had dynamite in store for very lengthened periods subject to extremes of temperature—some very high—and that it retained its original condition under some very trying tests.

The stability of dynamite has been practically confirmed by extensive and daily use in the mines on the Continent, and by a limited use in England, as well as by the large quantities which are stored at the factories. Beyond this, the most careful investigation has shown that there is not the slightest ground for apprehension on that score. Under continued exposure to the direct rays of the sun during the whole of the summer of 1868—an exceptionally hot one—not the slightest chemical change could be detected. The same results were obtained with a parcel of dynamite exposed for 40 days to a temperature varying between 150 deg. and 200 deg. Fahr. All nitrated, or rather hypo-nitrated organic compounds are liable to spontaneous decomposition—or what is understood by this hackneyed and ridiculous term—unless they are completely rid of free adhering nitric acid. The reason is that the free acid produces a local decomposition which sets hypo-nitric acid free, the latter producing a new local decomposition, and so on until sufficient heat is evolved to set fire to the compound. There is no difficulty in ridding dynamite of free acid ; but in the case of cotton, or any other fibrous substance, the utmost care is required, as free acid will adhere in spite of repeated washing. It will be seen that the method of percussively exploding the charges of dynamite adopted by Mr. Nobel is precisely similar to that devised by Mr. Brown for exploding gun-cotton, as described in a previous article upon the latter material. It is, however, but fair to state that Mr. Nobel used his percussion fuzes at the Merstham experiments, to which reference has been made, in July, 1868, whilst the experiments with gun-cotton exploded in the same way, were not carried out until the 22d of January, 1869.

It is generally conceived that nitro-glycerine, and consequently dynamite, is more dangerous and more easily exploded when in a frozen state than when liquid. But this conception is erroneous, inasmuch as it is really difficult to explode it when frozen, and we have a case in point to prove this. A charge of nitro-glycerine had become frozen in a hole at a quarry near Bangor, and was fired 3 times with gunpowder without being exploded. A small cartridge containing about ½ oz. of the liquid oil was then inserted in the blast hole on the top of the frozen charge, and on being fired, exploded the whole charge, which did its work most effectually. Some experiments made with frozen dynamite tend to prove that it cannot be made to explode even by percussive fire. Percussion fuzes have been exploded in it, but they have only either blown it away in fragments, or have set it on fire, so that it burned quietly away. These facts at once silence any theoretical objections which may be raised to this compound on the score of its explosiveness whilst in a frozen condition.

There can be no question as to the real value of dynamite as an explosive for mining purposes. This value is fully recognized in Germany, where depots have been established in every mining district throughout the country. A firm at Cologne, who are the largest manufacturers of blasting powder in Western Prussia, have long been converts to dynamite, and have taken up its agency. In Sweden and Norway the consumption is very large, as it is also in the United States and California. It would doubtless appear strange that dynamite—possessing as it does so many and great advantages—should be so little known and so very much less used in England. The truth is that dynamite would undoubtedly have had as great a run in England as on the Continent, had it not been that a short Act was quietly smuggled through Parliament during the Session of 1869. It is known as the "Nitro-glycerine Act," and it virtually prohibits the importation, exportation, manufacture, sale, or even possession of "every substance having nitro-glycerine in any form as one of its component parts or ingredients." The Act is a very snug little affair, and if it was not promoted by the gun-cotton party, why it ought to have been ; it cannot fail, however, to afford them much satisfaction. It will thus be seen that extraordinary impediments have been thrown in the way of the use of dynamite in this country, and the consequence is that not more than 20 tons have been sold in Great Britain since the Act was passed. Messrs. Webb & Co., of Bangor, are the agents for Mr. Nobel—whose factory is at Lauenberg—but they inform us they are literally doing nothing, although they have constant applications for the material. At several mines where dynamite has been tried, the managers are constantly pressing for further supplies, but of course to no purpose.

With regard to the power of dynamite, we may observe that its destructive action is estimated to be about 10 times that of an equal weight of gunpowder. If, therefore, we take the average work done by 1 lb. of gunpowder at 32,832 lbs. —an average obtained from actual practice in 6 different places, and in various kinds of rock—we get 328,320 lbs., or about 146½ tons, as the work done by 1 lb. of dynamite. Hence, although its cost is greater than that of blasting powder, its use is attended with great economy. We have ascertained this economy to be in one mine in Cornwall as much as 50 per cent., whilst it is stated that the St. John del Rey Mining Company doubled their workings at ⅗ the cost of gunpowder. We are also informed that this same company saves £1,000 per month by the use of dynamite as against gunpowder. The greatest economy results from its use in hard rock, a considerable saving being effected by its means in the labor of the miners, and in the time occupied in performing a given amount of work, as much fewer and smaller blast holes are required than when gunpowder is employed. We are not aware that any comparative experiments have been made with dynamite and gun-cotton, and which would afford data as to their relative power. Taking, however, the results of the Merstham trials already referred to, and those of the gun-cotton experiments in January, 1869, we should certainly say that dynamite was the stronger of the two. Our reasons for this conclusion are founded upon the circumstances that at the latter experiments 5 lbs. of gun-cotton failed to more than shake a palisade, which we think 5 lbs. of dynamite would have demolished. This question, however, can only be settled by comparative experiments, which at present there is but little chance of seeing carried out, at any rate in England.

The most recent modifications introduced by Mr. Nobel in the manufacture of explosive compounds, into the composition of which nitro-glycerine enters, are to be found in two kinds of blasting powder, which were introduced by him towards the close of last year. The composition of the two types of this powder is as follows: No. 1. Pulverized nitrate of barytes, 68 parts; charcoal of light texture, 12 parts; nitro-glycerine, 20 parts. No. 2. Pulverized nitrate of barytes, 70 parts; powdered resin, 10 parts; and nitro-glycerine, 20 parts. The charcoal is carbonized at a low temperature, and consequently still contains hydrogen. An addition of from 5 to 8 per cent. of sulphur to either of the above mixtures gives a powder which fires more briskly, but, at the same time, it increases the danger in the manufacture, carriage, and application of the powder. The method of using these powders is to place them in cartridge cases, the powder being covered with a little mercurial or other fulminate before the case is closed and primed. The cartridge is placed in the bore-hole and tamped in the usual way, and is fired either by a fuze or by an electric wire. The fulminate, acting on the nitro-glycerine, ignites the whole charge instantaneously.

In our opening remarks we referred to the dangerous character of nitro-glycerine, as illustrated by several catastrophes. In concluding, we would bear testimony to the comparatively harmless nature of dynamite, as evidenced by the Merstham experiments, and further by a circumstance which came to our knowledge in 1868. In that year a tremendous explosion of nitro-glycerine occurred at Mr. Nobel's factory at Stockholm, which destroyed the works. Close by was a store of dynamite, which, after the explosion, was found scattered about in all directions, but none appears to have been exploded. The further evidence of the safety of dynamite is of a negative character, and consists in the absence of any record of accident either in manufacture, storage, or transport. Two accidents have happened with dynamite while in use in mines, but they arose from sheer carelessness. In one instance the tamping was incautiously removed after a misfire, an operation which ought not to be allowed in any case; and in the other a half-witted miner, having heard that dynamite burned harmlessly in the air, lighted the fuze of a charged cartridge, and held it in his hand until it exploded. A third accident of a special character occurred at Wigan, where a workman was blasting a large mass of iron on a very hot day and with loose dynamite, not confined in paper cartridges. He fired the charge, which was not strong enough to break up the iron, and he forthwith commenced to recharge the hole with dynamite. While ramming the powder down with a wooden rammer it exploded, blowing the rammer out of the man's hand, and injuring him. He was by no means seriously injured, and would have recovered but for the circumstance that one or two small splinters from the rammer had entered his arm, and being saturated with nitro-glycerine they poisoned the flesh, and the man died in a fortnight. Three men were standing by at the time of the accident, one of whom had 8 lbs. of dynamite in a bag with him. The dynamite took fire and burned slowly away, slightly scorching the man who was holding it, but not hurting the other two men.

There can be no doubt that the explosion arose from the extreme heat of the iron consequent on the explosion of the first charge, the hot sun rendering the dynamite more sensitive, the ramming down of the powder while in this sensitive state causing it to be fired. This, in fact, was subsequently proved to be so by Mr. Webb—to whom we have already alluded—who took a lump of hot coke and placed some loose dynamite on it. The dynamite soon began to smoke, and after it had smoked awhile Mr. Webb touched it with a rod, and it immediately disappeared with a kind of semi-explosion. The experiment was repeated several times with the same results, and the accident would not have occurred if the bore-hole in the iron had been sponged out. These are the only accidents we can discover, and they are such as must and will occur, however safe the explosive may be to handle, where carelessness or thoughtlessness exists.

THE VENTILATION OF UNWHOLESOME MANUFACTORIES.

From "The Engineer."

Some time ago M. Charles de Freycinet, *Ingénieur des Mines*, was directed by the then French Imperial Government to visit the most important manufactories in England, France, Germany, and Belgium, in order to report upon the means actually adopted in the more unwholesome operations for maintaining the health of the people employed. The results of his lengthy examination, apparently extended over several years, have been given in four very important reports, to which our attention has only lately been directed, and from which we propose to make some extracts, more particularly referring to ventilation, or renewal of the air, as a means of getting rid of injurious vapors and gases, or also of substances in a state of minute subdivision. A general and elementary means of preventing the infection of the air by deleterious vapors consists in the use of very high chimneys, which are generally acknowledged to be all the more efficacious for this purpose the higher they are; and that this is the case, not merely at a given point, but in the entirety of the circle of their action, all the new coke ovens erected in Belgium are now officially required to disengage their gases into chimneys at least 45 ft. to 60 ft. in height. The application of tall chimneys receiving the gas from a group of coke ovens has notoriously effected quite a change in the county of Durham, where sometimes as many as 1,000 coke ovens are found congregated together. In the wine districts of France the smoke from lime and brick kilns has been found to injure the quality of the grapes, giving the wine made therefrom a sooty taste; so that unfortunate burners have been adjudged to pay considerable damages to the owners of neighboring vineyards. Tall chimneys have thus been made a necessity, and the nuisance caused to the town of St. Etienne by the numerous coke ovens has been completely obviated simply by their use.

Ventilation by means of fans, acting either in the buildings or directly on the apparatus of manufacture, is in general use in French factories for the preparation of white lead, the torrification of tobacco, dressing of leather, and in woollen or cotton manufactories. The infection of the general atmosphere is prevented by the use of chimneys and of condensation by water of noxious gases. In the preparation of soda, high towers of masonry, filled with coke, are employed for condensing the fumes. It is well known that workmen silvering mirrors are liable to mercurial trembling produced by the vapors. At Saint Gobain, Cirey, and Chauny, near Paris, the men are only employed at this work twice, or, at the most, thrice a week. All the windows are kept open in the wide and well-ventilated workshop. The flannel rubbers by which the mercury is spread over the tinfoil are fitted with handles nearly 4 ft. long. The mercury is kept in close cases, and the cloths through which it is passed in order to get purified are not beaten in the open air, but by a beater contained in a hermetically closed casing. Gilding with mercury, as is done by Messrs. Bonin & Co., of Paris, is rendered safer by covering the fire intended to vaporize the mercury by means of a glazed dome surmounted by an open chimney. The man works by passing his hands under the casing, which extends below his chest. The workshop is also kept well supplied with fresh air. No means are said to have yet been discovered for rendering the manufacture of chromate of potash a wholesome operation. At M. Clouet's, of Havre, most of the men suffer from an actual perforation of the nasal membrane, which seems to be due to the suspension of particles of chromate in the air. Another very unsalubrious manufacture is that of quinine, which causes singular effects on persons brought within its influence. In both cases, however—and certainly in the latter, as we shall see by an instance further on—preventive means can be adopted. Another unwholesome and laborious operation, is that of dressing millstones by hand—a process now much facilitated by the use of the modern diamond dressing machines. The working population of La Ferté-sous-Jouarre, the well-known quarry of French burr millstones, is said to be decimated by the considerable disengagement of stone and steel-dust which takes place in dressing the stones. Ten years or so of work of this kind is said to often result in mortal disorders. The very fine charcoal powder used by bronze metal founders to dust their moulds is another instance of the insalubrious effects of fine dust mingling with the air; but for such moulds for bronze metal work the use of potato-flour instead of charcoal-dust has generalized itself in Paris with very happy results in this way. The mills of M. Leroux, of Rennes, for grinding up bark, are fitted with exhaust fans and a sort of stive-room for gathering up the dust, which is considered, at equal weights, to be more powerful than common tan of the ordinary size. In the cotton-spinning factory of M. Octave Fauquet, at Oisel, the principal room, 9,000 metres in area, devoted to carding and spinning, is built in a peculiar way, with the triple intention of obtaining a uniform temperature, carrying off the impurities, and keeping up a certain moisture in the air. In order to prevent variations in the temperature of the roofing, due to changes in the weather, the surface of the arches forming the ceiling was built up with ordinary glass bottles, placed alternately with the bigger and the smaller ends in the direction perpendicular to the surfaces of the arches aforesaid. The empty spaces were filled in with mortar; and, on drawing out the bottles, there only remained a light and, so to say, spongy shell. On this was laid a continuous covering of plaster, and by this means a double ceiling was obtained, consisting of a mattress of air confined in a multitude of cells. All the double skylights are set in this ceiling. The air is renewed and the impurities are expelled by means of two large fans placed in a subterranean gallery. It is the fan near the carding machines that is most used to expel the dust. The circulation of the air is obtained by means of a system of conduits arranged under the flooring and opening into 30 gridded orifices. The moisture is obtained by introducing a spray of cold water into the gallery used for injecting the air. The arrangement is stated by M. de Freycinet to be a perfect success. In cigar factories it is not required to keep up a uniform temperature ; and there is also much less dust than in cotton-spinning factories. It is, however, necessary to get rid of the emanations from the moistened tobacco and from the numerous persons engaged in manufacturing the cigars. In works at Bercy, Nantes and Chateauroux, the air is sucked by fans from the outside; it circulates between the joists of the flooring on traversing the casings of the stove, where it gets heated in winter ; 8 cubic metres of fresh air per hour are allowed per person. Each workshop has 4 heating stoves. Other conduits, similar to those of admission, are led to exhaust chimneys over the roof. At M. Orsat's, of Clichy, white lead is ground between pairs of stones, the casing of which communicates with an exhaust fan. At Messrs. Engler & Krauss', of Paris, who use lead paste for enamelling insulating brackets of telegraphic wires, the enamel is ground up in hermetically closed mills. The chambers for manufacturing chloride of lime at the works of Mr. Charles Kestner, of Thann, communicate by a leaden pipe with the chimney. One or 2 hours before the entry of the workmen, a valve is opened at the same time as the doors. Suction sets up, and the gas is carried off by the chimney. The crucible furnaces for melting copper at the works of M. Maurel, of Marseilles, are placed in communication with the chimney of the steam boilers, which very effectually ventilates them. At the lead foundry of M. Lepau, of Lille, each of the melting furnaces is covered by a hood, fitted with a register, leading to a conduit opening under the ashpit of the steam boilers, so that communication can be cut off when not at work. The metalliferous vapors are thus thoroughly exhausted away. A somewhat similar process is employed by Messrs. Eschgar, Mesdach & Co., at Biache Saint-Vaast. M. Lepau also condenses the fumes; as the different exhaust tubes open into a chamber underground in communication with the steam boiler ashpits.

Speaking generally, very happy effects result in factories for treating mineral oils, and other fatty substances, varnishes, or for distilling wood, or sulphuretted hydrogen, by leading the vapors to the steam boiler furnaces to be there consumed. This is applicable in nearly all operations exercised on organic substances, and a considerable saving of fuel is often the result. For instance, at the soap-boiling works of M. Evrard, at Douai, the pans are fitted with a cast-iron semicylindrical cover, movable round a hinge, which can be raised more or less, as required. This cover is pierced with a hole by which the vapors can escape under the furnaces of the steam boilers; and at its end, the exhaust is intensified by a jet of steam. During the greater part of the time the cover is down, but when it has to be slightly raised for the introduction of the workman's stirrer, a cloth is lowered over the opening.

In Germany, and often under the stimulus of governmental interference, some very scientific mechanical and chemical means are adopted for preventing or carrying off injurious emanations. At Aix-la-Chapelle, the Prussian authorities have absolutely prohibited the grinding of needles unless the apparatus be furnished with a fan for exhausting away the fine particles of metal and stone thrown off in dry grinding. The Government requirements have also evolved two new machines for holding the needles mechanically. In the works of M. Schumacher, of Aix-la-Chapelle, for making steel pins, all the grindstones are fitted with fans. At M. Merck's pharmaceutical works at Darmstadt, where the poisonous belladonna is ground up in large quantities, a large bell, tightly jointed, suspended by chains from the ceiling, is lowered down on the mill after it has been charged with the belladonna, and is only raised up again when the grinding operation has been completed and all the dust has had time to settle. Experience has shown that this bell should be even without doors in its sides, as, whatever care may be taken, the fine powder still manages to pass through. At the works of M. Piret Pauchet, of Namur, Belgium, tan bark for tanners is ground up in three horizontal pairs of stones. The substance is introduced by a hole in the thickness of the upper stone, and each apparatus is contained in a metallic casing, to which is fitted the supply tube for the bark. Another tube communicates with a powerful fan, which exhausts the fine dust and propels it into a funnel on an upper story. At chemical works at Mannheim, managed by M. Gundelach, the men required to repair the leaden chambers for the sulphuric acid, or for chloride of lime, are covered with a sort of close helmet, supplied with air from an air pump through a flexible tube. This is also done at Worms and at Heilbronn.

The great extension of manufactures in Belgium, also coupled with a pretty stringent Government interference, have forced factory owners to have recourse to many ingenious means for obviating nuisances to the adjoining neighborhoods. At the works for the concentration of sulphuric acid, held by M. de Hemptinne, of Molenbeck-Saint-Jean, near Brussels, the platinum retort is cased in with masonry. The dome is pierced with a large hole covered by an hermetically closed plate of lead. Within the space thus formed between the retort and its covering is inserted a leaden pipe carrying off the vapors into the chimney. At the large paper mill of M. Godin, of Huy, where the coarsest rags are bleached by means of chlorine gas, the gas is led into stone cases, air-tight, which can be put into communication with a central chamber about 30 ft. high, and by which a powerful suction can be set up. At Ghent, and also Dusseldorf, whitelead is ground up with oil or water, in order to prevent the evolution of its injurious dust. White-lead is used in bleaching lace, and so much disease was thus caused amongst the lace workers, that the Belgian Government raised the question whether its use for this purpose should be abolished. One process now used consists in beating the lace inside a casing hermetically closed.

In the manufacture of ultramarine, by M. Leverkus, of Opladen, it is ground up within closed apparatus containing fans. As already observed, a singular disease affects the workmen preparing quinine and its sulphate—so much used as a tonic medicine. Herr Zimmer, at Sachsenhausen, near Frankfort, grinds up the bark in a moistened state, the ground up materials being afterwards treated in closed casings. In purifying the raw sulphate, the evaporating pans are kept in a distinct workshop, and under a covering fitted with an exhausting chimney. Generally, the different operations are carried on by self-acting machinery. At the establishment of M. de Roubaix, near Antwerp, for the manufacture of phosphoric matches, the five separate buildings in which are carried on the successive operations are all ventilated by means of a large central chimney, receiving the fire gases from the steam boilers, and, if necessary, from a special furnace. A large underground channel runs along the opposite sides of each building, and opens into the chimney. Wherever the phosphorus is placed, an opening in the wall is made to communicate by a pipe with the subterranean channel, and thus leads away the deleterious vapor ; the arrangements made for taking up the vapor vary with the nature of the operation. Thus, a large flat bell, set near the ground, is placed over the spot where the paste is formed. In the woollen factory of MM. Hauzem, Gerard, & Co., of Verviers, the combing machines are set up in a separate building, and are provided with fans. In the spinning mill two powerful fans exhaust the air from the two ends, while several openings in the flooring allow the entry of fresh air. The woollen stuffs are spread on a grid covering a large casing closed up at its other sides. A fan powerfully exhausts from the inside of the casing, while a current of hot air is led against the ceiling of the building. By this ingenious plan the workmen are quite free from the unwholesome atmosphere generally present where the vapors are allowed to disengage freely. At Ypres, the lime which has served for purifying lighting gas is, on cleaning out the cases, immediately mixed with the ashes from the fires, which process at once destroys all smell ; and the mixture, kept in a well ventilated passage, causes no inconvenience, and is sold as manure.

In England, the manufacturers themselves holding, in many instances, the local government in their own hands, sanitary ventilation is too often neglected ; though more favorable cases can be cited. Thus, fans are used at Messrs. Joseph Rodgers & Sons, of Sheffield, and at Messrs. Thomas & Sons, of Redditch, to exhaust away the fine particles of metal produced in the process of dry-grinding cutlery and needles respectively. The exhaust of the factory chimney used is for the same purpose at some other places. At the candle factory of Messrs. Price, of Battersea, the storehouse for the manufactured goods is ventilated by means of a cylindrical roof of thin plate, opening at the top into a number of small chimneys. The plate roof, getting heated by the least sunshine, a very powerful draught is created. The resulting effluvia on the river Thames are, however, sometimes very powerful. Manure factories in England are generally ventilated by chimneys of extraordinary height. In glue factories the vapors are burnt in the furnaces. At the manufactory of Mr. Crossfield, of St. Helens, the chambers wherein the chloride of lime is made are in communication by an exhaust pipe with the chimney of the works. On opening an opposite door a current of air is set up, and the chlorine in excess is quickly exhausted. At Messrs. Elkington's, of Birmingham, the air of the workshop where the silvering is carried on is sometimes filled with the considerable amount of hydrogen disengaged by the decomposition the water by the galvanic piles. It is got rid of by means of a column ventilator opening above the roof of the building. In the shops where the silvered or gilded articles are cleaned the acid vapors are disengaged under domes in communication with one of the large chimneys, or with a pipe within which burns a strong gas flame.

Generally, it is by artificial ventilation that the preparation of leather, the grinding of needles, the manufacture of phosphorus matches, the spinning of textile fabrics, the grinding of bark, and in general operations giving rise to the evolution of vapors or of dust, have been rendered much more wholesome. In other instances, such as the manufacture of fulminate of mercury and the concentration of sulphuric acid, preventive modifications in the manufacture have rendered actual ventilation unnecessary. Enamelling iron plate, for instance, is a very unwholesome operation, especially when the enamel embodies lead, and even arsenic; but metal enamelling pastes and powders quite free from lead are now getting into use. Analagous to this is the substitution of amorphous phosphorus for the white kind.

THE GREAT AUSTRALIAN TELEGRAPH.

From "Engineering."

The last advices from South Australia appear to show that there has been a hitch in the development of the Great Australian Telegraph line. Bravely as the enterprise has been entered upon and prosecuted, it has been found to present greater difficulties than had been anticipated in the first instance. Still the latest tidings which have come to hand with respect to the great work are not calculated to induce a feeling of despair as to its future, but merely show that the South Australian authorities have committed themselves to a more arduous task than had been at first imagined. The South Australian Government vessel, the Gulnare, while on her way from Palmerston to the Roper river, struck on a reef near the Verdon Islands, a group lying between Melville Island and Adam Bay, and within a comparatively short distance of Port Darwin. She contrived to return to Port Darwin, but on arriving there she was condemned, and the Bengal was chartered to take her place. Mr. Patterson, one of the superintendents concerned in the development of the line, had also reported loss of stock in pushing his way from the Catherine to the Roper, and had requested the Colonial Government to send reinforcements to the Roper. The South Australian Cabinet had accordingly met, and had resolved upon sending a steamer and also a sailing vessel, carrying additional horses and wagons, with their drivers and all necessary supplies, as requested. Mr. Todd, the South Australian Postmaster General and Telegraph Superintendent, was to leave by the steamer, in order to personally direct the completion of the great line and its opening for traffic.

The difficulties which have arisen occur at the northern end of the great line; the intelligence which has come to hand as to the central sections is relatively satisfactory. Two communications have been received in Adelaide, for instance, from Section E. The first, dated from the Third Main Camp on Gilbert's Creek, on September 1, refers to the fact that 61 miles of poles had been erected, but the ugly fact had been established that the line would have to pass for a considerable distance through country destitute of surface water; a well had been sunk, and water had been obtained at 17 ft., but it had not been ascertained whether the supply was likely to be permanent. This scanty water supply has always been considered to be the great drawback to Central Australia, although in some seasons there may be a greater quantity of moisture available than at other less favored periods. Another letter, dated September 20, states that the camp had been shifted to Tenant's Creek, latitude 19 deg. 33 min.; the work was then progressing well, and about 75 miles of poles were expected to be put up shortly. The communication is from Mr. Roberts, the second in command, and it states that Mr. Harvey has been well-sinking, and had struck water at 20 ft. Mr. Burt had been sent on to Newcastle waters to communicate with the Port Darwin end, news not having at that time arrived in respect to the Northern Territory sections. Several thunder-storms had occurred, and it is noted that Mr. Millner had passed beyond the end of Section E with his sheep, and was supposed to have reached the Newcastle waters. A previous account mentions that in passing the Davenport range, Mr. Millner lost 1,200 or 1,400 sheep by poison.

As regards the southern section—that is, the section nearest to Adelaide—it appears, according to the last advices, to have moved on well. At the date of the last reports the whole of Mr. Bagot's contract was poled. North of the Gums there were only 10 poles to the mile, but the contractor's men were engaged in putting up the intermediate ones, and this had been done for 28 miles north of the Peake. A party was busily erecting the wire, working from the northernmost end back to the Peake, and another lot of men had wired from Port Augusta to within 27 miles of Mount Margaret. A third party was at work planting the intermediate poles on the portion between the Gums and the Peake. Considerable progress was thus being made upon the whole, with what was expected to be the latest portion of the line—that is, the part between Port Augusta and the end of Section E. The operators for the interior stations arrived at the Peake all well on November the 6th, and they were to start forward in a few days. Rains fell early in November, and these were expected to greatly facilitate the construction and opening of the southern portion of the line. By Christmas day, in fact, it was anticipated that telegraphic communication would be established as far as the Macdonnell Ranges.

Such was the state at the close of November, 1871, of the great undertaking in which the South Australian Government has embarked. A telegram received through the enterprise and energy of Reuter's Telegram Company (Limited) brings us further tidings to January 5, 1872, and states that "telegraphic communication with Port Darwin in connection with the Australian cable is now partially completed." This is rather vague and unsatisfactory, as the intelligence appears to have occupied some 20 days in finding its way from Melbourne to London, and the great line might also have been said to have been "partially completed" in November. On the other hand, it must be admitted that the intelligence vouchsafed by Reuter's Telegram Company makes mention of no fresh misfortune having been experienced by the South Australian Government in the prosecution of the work to which it stands committed; and, under these circumstances, it is, perhaps, fair to assume that Adelaide, Melbourne, Sydney, and Brisbane will be in almost instantaneous communication with London before the spring has run its course. The prosecution of a great Australian overland telegraph seems destined to exert a large influence for good upon the future of Australian colonization. Port Darwin can scarcely fail to become the nucleus of an important settlement in the north of Australia, and the construction and maintenance of the overland wire must also add greatly to our knowledge of the interior of the vast island continent which has hitherto been practically a sealed book. On the other hand, if it should be found a matter of great expense and difficulty to maintain a telegraph line in the interior of Australia, the South Australian Government may yet rue the day in which it embarked in so arduous an enterprise. Moreover, there is almost a certainty that a competitive route will be opened up by the Queensland Government, which will not have so very much to do to carry a wire to Port Darwin. Perhaps, also, in time a telegraphic wire may also be carried round the western coast of Australia, from Port Darwin to Perth, and thence to Adelaide. But however doubtful the prospect which may be before the South Australian Government of recouping itself for the expenditure which it has made in carrying a wire across the Australian interior, we can but admire the courage with which it entered upon the work, and the perseverance with which it is carrying it on to the end.

Metallic bismuth, which is now largely used in the manufacture of pharmaceutical preparations, and in the composition of fusible metals, etc., has a high commercial value. The principal supply is derived from Bolivia.

THE PHOSPHATE SEWAGE PROCESS AT TOTTENHAM AND LEICESTER.

From "The Mechanics' Magazine."

The much controverted question as to the most practicable and efficacious method of dealing with town sewage, is in course of gradual solution, and may, it is to be hoped, ere long find a satisfactory settlement. The various committees that have been formed to inquire into the subject, and more especially the Reports of the Rivers Pollution Commissioners, have afforded reliable information of such an alarming character as to the impure condition of the rivers throughout the country, on account of the admission into them of every species of refuse, that the absolute necessity of adopting some system, in order, so far as possible, to remedy the evil, is now universally allowed. It is a matter that has deservedly gained the attention of scientific men, for the consideration of the subject involves many points upon which they alone are able to give a competent opinion. There can be no doubt, however, that the right place to dispose of the sewage of human dwellings is on the crop-producing lands; but how to get it there is apparently a somewhat perplexing problem. Within the past few years various schemes have been introduced to public notice, some of which aim at the purification of sewage before it is applied to the land, and these have been put upon their trial in different towns. The simple plan of irrigating the land with the sewage in its raw condition has been adopted in many places, where, up to the present time, it has been attended with successful results, so far as it is a means of disposing of the sewage; but the extent to which it can be carried must of necessity be limited, unless ample appliances be provided to convey the sewage to any required spot; and such an undertaking involves at the commencement a considerable outlay of capital for which an adequate return in the shape of interest cannot be confidently relied on, for experience has shown that, in general, sewage in the raw state has not yet attained a commercial value as a manure, at all proportionate to an estimate based on the extent of population. The difficulties to be encountered are numerous, no matter from what aspect the subject is viewed, and when any new scheme is brought forward, every one is anxious to examine its capabilities of dealing with the question at issue, since all are more or less interested in its satisfactory solution.

We propose, therefore, to describe a defecating system which has been patented by Professor David Forbes and Dr. A. P. Price, and to see with what success those difficulties have been met; the system about to be adopted by the local Board of Tottenham, to prevent pollution of the river Lea, and already adopted by the Town Council of Leicester, in substitution for the lime process, which has not been found efficacious in preventing the pollution of the river Soar. It has, therefore, substantial claims to a hearing.

The patentees affirm that their plan, which effects a precipitation of all solid matters, is superior to irrigation with the raw liquid, inasmuch as it purifies the sewage and produces a manure more available for agricultural purposes, and of an equal if not greater commercial value. The precipitating agent employed is a natural phosphate of alumina, which has been discovered in very large quantities in the West Indies—indeed, it is stated that an island called Alto Vela contains on a moderate computation, upwards of 9,000,000 tons thereof. Upon submitting this material to chemical analysis, Professor Forbes found it to consist of one equivalent of alumina, one of phosphoric acid, and five of water; and three samples of the phosphates showed the following percentage composition:

	No. 1.	No. 2.	No. 3.
Phosphoric acid	38.96	37.09	33.11
Alumina	27.06	26.08	21.57
Peroxide of Iron........	2.68	2.76	2.07
Lime	1.94	2.09	1.03
Insoluble matter........	6.70	9.10	17.00
Water, etc.	22.66	22.88	22.22
	100.00	100-00	100.00

The process of its application in the deodorization of foul sewage is very simple.

In the first instance it is reduced to a powder and then submitted to the action of sulphuric or hydrochloric acid, in the relative quantities of 10 parts of phosphate to 7 of acid, by which means it is decomposed and rendered soluble, when it has the appearance of a thick paste. The solution thus obtained—which is stated to be so powerful an antiseptic and disinfectant, that it effectually arrests further putrefaction, and renders the most fetid matter free from all offensive odor—may be used in this concentrated form, or it may be diluted with water (which is preferable) until it assumes a liquid state. Ii is now in a proper condition to be employed, and as the sewage is pumped into reservoirs or tanks, the desired quantity of the soluble phosphates is permitted to flow in and mix with it, an agitation being sustained during the process so as to insure a thorough admixture. When the tanks are full the sewage thus treated is allowed to remain tranquil and precipitation immediately commences. All the solid matter previously held in solution, which is now deodorized, gradually subsides and leaves a transparent effluent water, free from offensive smell or disagreeable taste, and differing but little from ordinary river water. But to remove any doubt that may exist as to the admissibility of this supernatant water into a stream, the patentees effect a still greater clarification by adding, during the operation, a small quantity of milk of lime, which causes a precipitation of the phosphates in solution—a result that is known by the "sewage acquiring a neutral or alkaline reaction." It is not pretended that this water is suitable for drinking, although Professor Forbes says it may be used for that purpose without repugnance; but it is alleged that it may be discharged into any river without the least apprehension of causing a nuisance, and in support of this assertion, Dr. Letheby states that "fishes can live in it, and, most important of all, it will remain for months in hot summer weather without showing any tendency to putrefy or emit a disagreeable odor; there is no doubt, therefore, that such water may be freely and safely discharged into a watercourse."

If it be determined, on the other hand, to utilize the sewage of a town by irrigation, or in those cases where land has already been prepared for that purpose, an equal advantage may be derived from the application of this process, so as to separate the solid matters from the liquid, and to remove their putrescence before they are distributed over the land; as it is not certain that any beneficial end is promoted by preserving an extremely offensive odor, which only pervades the surrounding atmosphere, or that slimy fetid sewage can best contribute to the growth of plants when applied in that condition; and, therefore, a precipitating plan, such as the phosphate process, capable of defecating the sewage without detracting from its agricultural value as a fertilizing agent, would be no disadvantage for irrigation; moreover, it has been stated on competent authority, that much benefit is gained, in utilizing sewage for this purpose, by first separating from it all, or a greater part, of its solid ingredients. The patentees particularly direct attention to this as a distinguishing feature of their system, and Professor Voelcker is of opinion that the effluent water is "more valuable bulk for bulk for irrigating purposes than the raw liquid," because, instead of losing any of its mineral fertilizing matters, it has become slightly richer in saline ammonia—a conclusion arrived at after a careful analysis of an imperial gallon of Tottenham sewage which gave the following results:

Constituents per Gallon.	Before Treatment.	After Treatment.
Soluble matters:	Grs.	Grs.
Organic matter and combined water (loss in drying the residue at 280° F.)	6.35	5.74
Carbonate of lime	10.80	6.44
Sulphate of lime	16.45	26.43
Carbonate of magnesia	7.18	7.58
Oxide of iron and alumina	.48	.17
Phosphoric acid	.58	.25
Chloride of Sodium	10.56	10.08
Alkaline carbonate (determined by difference)	4.05	5.75
Soluble silica	.70	1.01
Total solid matter in solution	57.15	63.45
Suspended matters:		
Organic matter	11.41	0.00
Containing nitrogen	.64	
Equal to ammonia	.76	
Mineral substances	5.11	0.00
Total suspended matter	16.52	0.00

The total organic and mineral matters, therefore, both in solution and in suspension, amounted to 73.67 grains in the raw sewage, while the effluent water contained 63.45 grains in solution, but no perceptible and weighable matters in suspension, which shows the extent of purification attained by the use of the phosphate of alumina.

A sample of London sewage, treated and analyzed by Dr. Letheby, gave similar results as to clarification, though the percentage of each constituent of the London sewage was considerably greater than that of Tottenham, which is explained by the fact of the former containing more solid substances than the latter. In those cases where the supernatant water is to be used for the purposes of irrigation it is not necessary to add the milk of lime, for the soluble phosphate which the lime precipitates, is a most important ingredient in assisting the growth of vegetation.

ILLUMINATING GAS.

From "The American Exchange and Review."

Among the requirements of civilized life, there are few which assert themselves with more emphasis than some convenient form of artificial light. Whether we consider the subject in its moral, social, or economical relations, and from whatever standpoint we may view the question, the fact remains, that light is one of the chief necessities of man, and in some form or other its artificial production has become more general and available in a direct ratio with the advance of knowledge and civilization. Among the applications of science to the arts, none have been more productive of useful results than those crude experiments in destructive distillation made by different investigators during the last century, which finally culminated in 1792 in the manufacture of illuminating gas. Whether regarded as a luxury or a necessity—for in both these aspects it presents its claims on our attention—its benefits have made themselves felt in all parts of the world ; and wherever culture and refinement have their abode we find this form of artificial light an indispensable requirement. "It has extended the available term of man's life by giving the hours of the night to his use. It has, by the social intercourse it encourages, polished his manners and refined his tastes, and, perhaps as much as anything else, has aided in his intellectual progress."* Its influence in reducing the tendency to crime in towns and cities has been recognized. So accustomed have we become to its use, and so constantly do we rely upon it, both in domestic economy and in the demands of industry, that we are prone to accept its benefits simply as a matter of course, and to frequently overlook the importance of the art which furnishes us with so efficient a service.

The history of illuminating gas has been often recounted. From the most authentic descriptions of its rise and progress, it is evident that its manufacture was suggested by the experiments made with natural gas issuing from the earth in close proximity to coal seams. In the writings of ancient authors, mention is made of perpetual fires which were burned on altars consecrated to the worship of mythological deities. Strabo and Plutarch refer to these mysterious fires ; while Herodotus, Vitruvius, and other early historians, allude to the bituminous wells of the island of Zante, whence issued streams of inflammable vapor, which were used to inspire the multitudes of superstitious worshippers with profound reverence for sacerdotal authority. In India and China these wells have been known from remote antiquity ; and it is said that in the latter country the gas thus naturally exuding from the ground has for a long time been conveyed in pipes made of bamboo, and used for boiling salt. Gas wells of this description abound in various parts of the world ; one of which, in England, was probably the means of suggesting the artificial production of gas, and its utilization as an illuminating agent. In this country several wells of more than ordinary interest have been discovered, yielding large volumes of gas of considerable illuminating power. Among them may be mentioned those in the town of Fredonia, New York, where two companies furnish light to a village of 3,000 inhabitants,

* Draper.

produced solely by burning the natural gas as it rises from the ground. At Bloomfield, in Ontario county, New York, there is a well, from which, according to the estimates of Prof. Henry Wurtz—one of the best authorities on the subject—the daily flow of gas is upwards sf 400,000 cubic feet. In Ohio, near the town of Gambier, remarkable wells of a similar character have been described by Prof. J. S. Newberry, where the gas has constantly flowed without apparent diminution of volume since 1866, and which, on being ignited from the orifice of a 2-in. pipe, produces a flame 20 ft. or more in length. Similar phenomena have likewise been observed in the petroleum region of Pennsylvania.

A stream of carburetted hydrogen gas issuing from a spring in the Wigan coal district of Lancashire, was observed in 1667 by Mr. Shirley, who communicated a description of it to the Royal Society of London. In his account of this phenomenon, it was rightly conceded that the "inflammable air" originated in the underlying coal seams. As the gas floating on the water of this spring could be ignited, it was generally believed that the liquid was inflammable, but Mr. Shirley demonstrated the error of this idea, and showed that it was merely the gas rising from the water, which burned. In 1726, Dr. Hales made a number of experiments on destructive distillation, using Newcastle caking coal, from which he obtained a gas which he burned for amusement. The quantity of this gas agreed very closely with the results of modern operations on a large scale. The experiments described by the Doctor in his work on "Vegetable Statics" must have been conducted in a very small way, as he mentions having used but 158 grains of coal, from which he obtained 180 cubic in. of gas. This yield is equivalent to about 8,500 cubic ft. per ton. But prior to the publication of Dr. Hales' book, the Rev. John Clayton had amused himself with experiments on the distillation of coal, which he did not publish, however, until 1739. In a letter written before this date to Hon. Robert Boyle, he gives a very quaint account of his operations, wherein he states that having introduced a quantity of coal into a retort, and placed it over a fire, he continues: "At first there came over only phlegm, afterwards a black oil, and then likewise a spirit which I could no ways condense; but it forced my lute or broke my glasses. Once when it had forced my lute, coming close thereto in order to try and repair it, I observed that the spirit which issued out, caught fire at the flame of the candle and continued burning with violence, as it issued out in a stream, which I blew out and lighted again alternately for several times. I then had a mind to try if I could save any of this spirit; in order to which, I took a turbinated receiver, and putting a candle to the pipe of the receiver whilst the spirit arose, I observed that it catched flame, and continued burning at the end of the pipe, though you could not discern what fed the flame. I then blew it out and lighted it again several times; after which I fixed a bladder, squeezed and void of air, to the pipe of the receiver. The oil and phlegm descended into the receiver, but the spirit, still ascending, blew up the bladder. I then filled a good many bladders therewith, and might have filled an inconceivable number more; for the spirit continued to rise for several hours and filled the bladders almost as fast as a man could have blown them with his mouth, and yet the quantity of coal I distilled was inconsiderable. I kept this spirit in bladders a considerable time, and endeavored several ways to condense it, but in vain; and when I had a mind to divert strangers or friends, I have frequently taken one of these bladders, and pricking a hole therein with a pin, and compressing gently the bladder near the flame of a candle till it took fire, it would then continue flaming till all the spirit was compressed out of the bladder; which was the more surprising because no one could discern any difference in the appearance between these bladders and those which are filled with common air."

In 1733 a communication was made to the Royal Society by Sir James Lowther, on the subject of "inflammable air" which escaped from a coal mine near Whitehaven, which readily ignited, and was with difficulty extinguished. This gas was also collected in bladders, and burned in the presence of members of the Society. It attracted much attention, and seems to have produced a lasting impression, for as late as 1765 a proposal was made to convey the gas in pipes to light the town;

but the idea was regarded as chimerical, and was soon abandoned. The experiments of Mr. Clayton, although for a time apparently forgotten, seem to have supplied the germ from which subsequent developments sprung, for they partook more of the character of philosophical investigations than any of the hap-hazard essays which preceded them.

In alluding to the history of this important branch of industry we cannot pass over the observation of Dr. Watson, that coal gas is unaltered by being passed through tubes immersed in water; or, in other words, that the condensation of some of its constituents does not impair its illuminating properties. This fact is noticed in the "Chemical Essays" of this gentleman, published in 1767. Other experiments of this nature continued to be performed by various persons, but with little or no practical results. In 1787 Lord Dundonald, a Scottish nobleman, secured a patent for making coal tar—or, more properly speaking, coal oil, for this was the substance he desired to produce. In condensing this product, the gaseous body eliminated by the distillation of coal was collected for amusement and curiosity; and no other purpose than that of the entertainment of his friends seemed to inspire his exertions. These investigations, however, were not without their fruit. A countryman of his Lordship, by the name of Murdoch, then living at Redruth, in Cornwall, who had read of the experiments above described, was led to investigate the nature of the products of distillation, and extended his researches to the volatile bodies obtained from peat, coal, wood, and other combustibles. These investigations were pursued with some degree of system, and it was ascertained that by properly regulating the processes of carbonization and condensation, a uniform product of high illuminating power might be obtained. The practical mind of Murdoch soon appropriated the idea, that by constructing receptacles for the gas, and conveying it through pipes, it might be manufactured and utilized on a large scale. He lighted his own house in this manner, conveying the gas in pipes about 70 ft. from his miniature gas works, and likewise constructed a portable gas lantern which he carried with him at night, much to the discomfiture of the superstitious peasantry of his neighborhood, who strongly suspected him of witchcraft. In 1798 Murdoch erected gas works at Messrs. Boulton & Watt's Soho foundry, and having entered into the employment of that firm, he personally superintended the operation, and gradually perfected the details of the manufacture. That gas illumination, as illustrated by its employment at this factory, was a success, cannot be doubted; and yet several years elapsed before it was generally adopted. In 1802, at the illumination in honor of the peace of Amiens, the superiority of the display produced by the Soho foundry was so marked that general attention was attracted to the new method of illumination, and its use gradually extended. A number of large cotton mills were lighted by gas about the year 1805. The Lyceum theatre of London was the first place of amusement which employed it, and in a short time, its advantages having become better appreciated, its use became more general. But notwithstanding the fact that these advantages obtained a wider recognition, some opposition was manifested to its introduction. Grave predictions of danger were uttered, and no little ridicule was cast upon the project. When Napoleon was informed of the subject, he remarked: "*C'est une grande folie.*" Sir Walter Scott was no less incredulous, and said that he feared London would be on fire by it, from Hackney gate to Tyburn; while Lord Brougham declared that "the idea was worthy of the philosopher who proposed to extract sunbeams from cucumbers"—a remark, by the way, which, though uttered in a spirit of irony, in the light of modern scientific opinions contains elements of sober reality. Even Sir Humphrey Davy considered the idea of utilizing gas so ridiculous, that he contemptuously asked "if it were intended to take the dome of St. Paul's for a gasometer."

As soon as gaslight became firmly established in England, its merits claimed recognition on this side of the Atlantic, and in 1816 the first American gaslight company was chartered to light the city of Baltimore. Six years later, in 1822, Boston adopted the new method of illumination; while the old New York Gaslight Company, which lights the city from Grand street to the Battery, was chartered in 1823. Brooklyn and Bristol, R.

I., were lighted in 1825. In 1830 the Manhattan Gaslight Company of New York, now the largest and wealthiest in America and fourth in size in the world, was chartered. The district of this corporation extends from Grand street to Thirty-fourth, and from river to river. Other cities pronounced in favor of the new light as follows: New Orleans in 1835, Philadelphia and Pittsburgh in 1836, Louisville in 1838, Cincinnati in 1841, Kensington (Philadelphia) in 1844, Albany in 1845. From this date gas works multiplied with rapidity, and as the superiority of the new light became evident, cities and towns in all parts of the country were soon supplied with it.

The Baltimore gas works were originally constructed to make gas from coal tar, but this plan proved a total failure, as might have been predicted. After this unsuccessful experiment, the works were reconstructed by an English engineer, but this change not proving satisfactory, they were again remodelled, and gas was made from bituminous coal. In Boston a mixture of coal and rosin was used, while in the two New York companies rosin alone was employed. All of these works were deemed more or less defective, and when, in January, 1833, the question of erecting gas works in Philadelphia was brought before the councils, a committee was appointed to consider the question and to make a report. In January, 1834, it was resolved to send an engineer to Europe for the purpose of investigating the best gas works there in operation, and to obtain such information as might be useful in erecting works in the city. The late Samuel V. Merrick was selected for this mission, and in furtherance of his instructions he sailed in March, returning in December of the same year. Notwithstanding a violent opposition to the project, gas works were erected by Mr. Merrick, and on the 10th of February, 1836, Philadelphia was first lighted with gas.

All substances of an organic nature when exposed to a high temperature in close vessels, undergo a remarkable transformation. If the experiment be performed in a retort, and that portion which is volatilized by the heat be cooled and collected, it will be found that the original substance has been split up into three distinct bodies, viz., the solid coke which remains in the retort, tarry matters (including water), which condense to a liquid, and permament gas. A still further examination of these products would disclose the fact, that, although they present a homogeneous appearance, they are really mere mixtures of various bodies, which are capable of minute subdivision ; and that the liquid tarry matter contains substances which, when isolated, assume a solid form. Complex as these bodies, they are essentially composed of but two of the elements—carbon and hydrogen—although they include notable quantities of other elements, which, however, are regarded as impurities, and which, in the details of gas making, are eliminated as completely as possible. Among these objectionable substances are oxygen, nitrogen, and sulphur, which exist in various combinations, and unless removed from the finished product, greatly impair its quality.

A number of raw materials are available in the manufacture of illuminating gas. Almost every combustible body, when subjected to destructive distillation, yields gaseous products suitable for generating light. Coal, wood, peat, oil, rosin, fats, bones, and a variety of other substances, have been used ; but, generally speaking, bituminous coal may be said to be, *par excellence*, the natural source of gas ; and as such we find it almost universally employed, although the other substances above mentioned are sometimes used when local considerations render their adoption desirable.

Of the coals which are included in the generic term bituminous, there are many varieties, some of which are admirably adapted to the manufacture of gas, while others are of too inferior qaality to justify their employment. As a general rule, it may be said that the larger the quantity of volatile matter yielded by a coal, the better it is fitted for the gas works; and yet this rule is not without its important exceptions. The English cannels, which are regarded as the best gas coals, vary in their content of volatile constituents, ranging from twenty-seven per cent., in the Washington, to sixty-nine per cent., in the Boghead, with a long list of other coals of the same variety, intermediate between these two extremes. In Great Britain cannel coal is sometimes used alone as a source of gas, but it is generally distilled in conjunction with ordinary bituminous or caking coals, for the purpose of enriching the gases produced from the latter. This latter variety of coal is the main dependence of the gas works. In this country it is used almost exclusively; the few exceptions being in large cities near the seaboard, where certain proportions of English cannel are mixed with it. The advantages of ordinary bituminous coal consist in the fact that it is cheaper than cannel, and while it yields a gas somewhat inferior in illuminating power, it produces a coke of great excellence, which cannel does not; and as this material is one of the most important residual products of gas works, its quantity and quality are subjects of considerable moment. Moreover, the quantity of sulphur contained in ordinary bituminous coal is generally less than that in cannel, which is a decided advantage.

Most persons are familiar with the appearance of gas works. Located generally on the outskirts of towns, in places convenient either to water or railway communication, their numerous buildings, gas holders, etc., form conspicuous objects. In the manufacture of this illuminating agent, coal in charges of from 120 to 160 lbs. is quickly thrown into retorts, which are maintained at a bright red heat, from which the gases and vapors are conveyed away by means of upright iron pipes projecting from the front end of the retorts, and technically known as standpipes. After being charged, the retorts are quickly closed, the lids being luted, and forced against the mouthpiece either by means of a screw or a lever, so that they make a gas-tight joint. An improvement in retort lids has been lately introduced in the Dublin gas works, where the lids are hung on hinges and have machine-turned edges, which are brought in contact with the mouthpiece of the retort, which is also turned true, and the necessity for luting is obviated. The lids are gas-tight, and are held in position by means of a lever. A single charge remains in the retorts usualy about six hours, at the end of which time the lid is removed, and the gas remaining in the retort is ignited, so that it my quietly burn away while the coke is withdrawn. This is accomplished in a few moments, when a fresh charge is thrown in, and the evolution of gas goes on almost without intermission.

From the standpipe the gas passes through the dip-pipe into the hydraulic main, which is a large tube or trunk, usually made of cast iron, extending along the whole length of the retort house. The dip-pipes terminate in this main, their extremities extending 3 or 4 in. below the level of the liquid in the main, thus preventing the return of gas which has passed the end of the pipe. When the gas works are first put into operation, the hydraulic main is half filled with water, but this fluid is soon displaced by the heavier tar which condenses from the crude gas, so that in a short time the liquid contents of the main consist almost wholly of tar. Through this liquid the gas bubbles as is is eliminated from the retorts, depositing additions to the fluid contents of the main in the shape of tar and ammonia water, which my means of suitable pipes regulating their level, flow off to their appropriate receptacles.

From the hydraulic main, the gas, somewhat cooled, but still containing many condensable products, passes on to the condensers; but as in many works different intermediate methods are employed to cool and wash the gas, a brief reference to the various steps resorted to in this stage of the process may be advisable; although it must be premised that in many small gas works some of these processes are omitted altogether. In some instances the gas is caused to pass through a depth of several inches of water, which removes a portion of the ammoniacal products, and causes a further deposition of tar, while sometimes the gas is scrubbed by being compelled to pass through layers of moistened coke, and at others, subjected to streams of water conveyed through rose-jets. Many engineers, however, still oppose the use of the scrubber, or any direct contact of the gas with water, the reason alleged being that this treatment reduces its illuminating power. The condenser proper, in which the final cooling takes place, consists of a series of upright iron pipes, sometimes exteriorly cooled by water and sometimes by air. By these methods of cooling, the gas which leaves the hydraulic main in a heated condition is discharged into the purifiers at a temperature but little higher than that of the atmosphere—sometimes, indeed, where water condensation has been used, below it.

The earliest method of purification, known as the wet lime process, was introduced by Mr. Clegg, an eminent English engineer, whose practical mind soon became convinced of the necessity of removing the noxious products of the combustion of gas, by the influence of which much damage was done to pictures, gilding, and other ornamental objects. By this process, ordinary caustic lime was mingled with water in the proportion of one bushel to forty-eight gallons, and through this mixture the gas was compelled to bubble. As far as efficacy was concerned, this method of purification was satisfactory; but in the economy of manufacturing operations, it was found that the pressure upon the retorts, which was induced by the gas being compelled to pass through several inches of liquid, caused a decomposition of the richer hydrocarbons, and a corresponding deposition of carbon in the retorts, as well as creating a variable amount of leakage from the latter. These objections resting on valid grounds, endeavors were made to obviate them, which was accomplished by Berard, who introduced purification by means of dry lime. The apparatus required by this modification consists of a series of receptacles, generally square in form, in which are placed a number of trays, containing moist slaked lime, spread in layers of 2 or 3 in. in thickness. Through this substance the gas is passed, and when it emerges, after having traversed successive layers, it is finally discharged into the gas-holders, whence it is distributed to consumers.

From the foregoing brief, and, in the absence of illustrations, necessarily imperfect description of the manufacture of gas, it will be seen that the process is comparatively a simple one, and yet there are questions continually presenting themselves in the routine of operations, which demand no little scientific and practical knowledge; hence we generally find gas works placed under the supervision of persons of more than ordinary intelligence. In our large cities, gas engineers are generally selected on account of their scientific attainments, which include not only a reasonable acquaintance with the principles of chemistry, but more especially a knowledge of the physical properties of fluids, practical experience in the construction of buildings, furnaces, and the like together with such other branches of information as are constantly required in the business. In England, and in all countries, where large gas works abound, the profession of gas engineering includes, among its votaries, men of the highest culture and education; and the literature of this branch of technology has been enriched by contributions which are indispensable in every well-appointed scientific library.

Although more than 70 years have elapsed since coal gas was adopted as a source of artificial light, yet the principal features of its manufacture maintain a remarkable conservatism; and, with few exceptions, the changes which have taken place in the interval have partaken more of the nature of perfecting the apparatus employed than any real improvement in the process itself. This process, conspicuous alike for its simplicity and for the fact of its being the "realization of profound scientific research," is essentially the method introduced by Murdoch and perfected by Clegg and Berard; and although the labors of these eminent engineers have been somewhat supplemented by the experience of their successors, yet no radical improvement has been effected. The three steps into which the manufacture may be divided—carbonization, condensation, and purification—are virtually, in theory and practice, the same operations as were introduced by these pioneers of the profession. Perhaps one exception may be made to this assertion, in the substitution of oxide of iron for lime in the purifiers. But when we take into consideration the fact that this change was made, not for the purpose of improving the product, but chiefly, if not entirely, to obviate the foul odors arising from the spent lime, it can hardly be classed with inventions strictly intended to perfect the process of making gas. Purification by means of oxide of iron was patented in London in 1840, and since that time a number of modifications of the process have been perfected; but their adoption has been far from general. In London and a few other cities, gas companies have been compelled, for sanitary reasons, to resort to some form of oxide of iron purification. In New York the Board of

Health recently insisted on the substitution of this process for lime purification, by the companies embraced within the metropolitan district.

A brief allusion to the impurities contained in crude gas, and the means employed for their removal, may not be uninteresting, and in order to arrive at a correct comprehension of this process, it will be necessary to revert to the products of the distillation of coal. As we have before remarked, these products exist as solids, liquids, and gases. Dismissing the familiar subject of coke from our attention, the other results of the carbonization may be classified as follows : First, those which are permanently gaseous at the ordinary temperature of the atmosphere ; second, those which, though gaseous when subjected to the temperature of the retort, by perfect condensation assume a liquid form ; and third, the solid constituents. Among the products of the first class are olefiant gas, acetylene, hydrogen, marsh gas, carbonic acid, carbonic oxide, sulphuretted hydrogen, etc. In the second class are included benzole, naphtha, aniline, carbolic acid, bisulphide of carbon, creosote, toluole, etc., while among the constituents of the third class are various salts of ammonia, naphthaline, paranaphthaline, paraffine, etc. The bodies constituting the last two classes are embraced in the tar and ammonia water which flow from the hydraulic main, although certain proportions of them sometimes escape condensation, and pass on with the permanently gaseous products. The condensation of these bodies is a matter of some importance, especially in cold weather ; for if too large a proportion of them are distributed with the gas, they are apt to condense in the pipes, sometimes to such an extent as to stop the flow of gas.

Of the gaseous bodies enumerated in the first class of products, the removal of the carbonic acid and sulphuretted hydrogen demands great care. The former of these compounds greatly impairs the illuminating power of gas, while the latter by its combustion eliminates sulphurous acid, which exerts a deleterious influence on gilding, pictures, and other decorations. These substances are readily absorbed by lime, and if the process of purification be properly conducted, there is no reason why more than mere traces of them should be found in the gas. Another compound of sulphur which exists among the liquid products, but which is so volatile that it freely passes the condensers, is much more difficult to remove. This is the bisulphide of carbon, which is the source of nearly all the sulphur found in the analysis of gas.

The permanently gaseous products of the carbonization of coal, those which form the object of manufacture, are marsh gas, or light carburetted hydrogen, with some olefiant gas, or ethylene, and traces of acetylene. When ordinary bituminous coal is alone used in the retorts, the product contains but a small proportion of the two latter ingredients, being chiefly composed of marsh gas, which possesses a lower degree of illuminating power, as well as a lower specific gravity. As before remarked, cannel coal—which yields a larger proportion of olefiant gas, having a much higher illuminating power—is sometimes used with bituminous coal in varying proportions. In the Manhattan gas works of New York a mixture of equal weights of cannel and caking coal is used in the winter, while the summer proportions are one-third cannel to two-thirds of caking. The reason of this variation is because in winter the luminous gases and vapors suffer from condensation caused by cold weather, whereby the quality of the product would be impaired unless restored by a larger proportion of richer constituents.

The residual products of gas works form important objects of attention, and upon their proper treatment depends much of the prosperity of the business. Coke generally commands a ready sale, and although a considerable proportion of this product is used to heat the retorts, a large surplus is made. Coal tar is another important residue, the uses of which are extending in every direction. Within the past few years the investigation of the various products of this complex substance has opened up new fields of study, and rapidly advanced the scope of organic chemistry. It has been but a short time since the discovery of the beautiful aniline series of colors, which now form such important objects of manufacture, and from which tints are derived rivalling the richest colors produced from other sources. In addition to these products, pitch, creosote, carbolic acid, naphtha, and benzole are manufactured from the tar, together with a number of less important hydro-carbons.

The ammonia liquor which condenses in the hydraulic main along with the tar, and which floats upon the surface of the latter, is the source of all the salts of ammonia of commerce. It is converted into either sulphate of ammonia or sal ammoniac, by the addition of sulphuric or muriatic acid, as either salt may be required, and evaporated to crystallization ; but this method is slow and expensive, on account of the great amount of evaporation necessary. In the manufacture of sulphate of ammonia, a much better way is to transfer the liquor into a boiler, and to add milk or lime, and then to blow steam into it. The ammonia is rapidly liberated in a gaseous form, and conveyed through pipes into a lead-lined tank containing sulphuric acid of 60 degrees. In a short time crystals of the sulphate are formed, which are raked out on a lead-covered inclined shelf to drain, the drippings being allowed to run back into the tank. In Europe, the ammonia liquor is utilized in nearly all gas works, but in this country, with the exception of a few works in large cities, it is allowed to waste. Ordinary English bituminous coals yield about thirty pounds of sulphate of ammonia per ton.

The refuse lime which has fulfilled its office in purifying gas, is generally disposed of at cheap rates for fertilizing purposes. In some localities it is used to manufacture hyposulphite of lime, which, by treatment with carbonate of soda, is converted into hyposulphite of soda, but its employment in this way is very limited.

Although, as we have remarked, the process of manufacturing illuminating gas is eminently conservative, yet patents without number have been taken out in most civilized countries, for the purpose of effecting supposed improvements. So far as inventions essentially relating to the chemical process itself are concerned, it is safe to say that a vast proportion have been utterly worthless. One of the most prolific sources of these innovations has become manifest in the numerous delusions in which water-gas has loomed up as a veritable *ignis fatuus ;* holding forth its alluring promises, ever doomed to certain disappointment. To give a more retrospective glance at these chimerical schemes would fill a volume of no moderate dimensions ; and we must be content with simply a brief allusion to them and to the principles which underlie the attempts to utilize water in this branch of technology.

It is a fact well known to chemists, that certain metals possess the property of decomposing water at ordinary temperatures, in which reaction the oxygen of the water combines with the metal, forming an oxide, while the hydrogen is liberated in a gaseous state. The metals sodium and potassium afford illustrations of this fact. Other metals, among which are iron and zinc, decompose water or steam at a red heat, with a similar reaction; while incandescent coke or charcoal possess the same property, but in this instance the oxygen of the water combines with the carbon, forming a mixture of carbonic oxide and carbonic acid and hydrogen. Water may be likewise decomposed into its gaseous elements by electricity. Upon the application of one or the other of these methods of obtaining hydrogen have rested the claims of water-gas inventors. In the long list of patents which have been obtained in this special department of technology, the first of which we have any record was that of Vere and Crane, of England, bearing date in 1823. Their process claimed the introduction of water or steam into a gas retort while in operation. A short time subsequent to their alleged invention, Ibbotson patented substantially the same process. In 1830, Pinkus and Collier followed with a patent very similar in its provisions, and in the same year Donovan succeeded with a process in which the gases caused by the decomposition of steam by red-hot coke were impregnated with the vapors of turpentine, naphtha, and other hydro-carbons. In 1834, Seligue, Jobard, and Mollerat, three Frenchmen, patented processes very similar to each other, and almost identical in principle with Donovan's. In the following year Gilbert Sanders took out a patent in England, using the old familiar design of steam and red-hot coke. In 1847, White's process of decomposing steam by red-hot iron was brought out; and two years later Gillard patented in France a water-gas process, in which he obtained hydrogen by decomposing water by the magneto-electric machine, subsequently rendering the gas luminous by passing it through volatile hydro-carbons. In 1850, Paine attempted to astonish the world by his process, which was almost identical with that of Gillard, but which was claimed by its inventor to possess the remarkable power of converting water "entirely into hydrogen, or entirely into oxygen, at will." The wonderful claims made in behalf of this "invention," and the extravagant assertions made by its patentee, are fresh within the memory of many of our readers. Since this time water-gas patents have been issued with a rapidity which almost exceeds belief; and numerous self-styled inventors have exhibited considerable ingenuity, not in the processes devised, but in so concealing old, exploded, and worthless methods behind a mass of cunningly arranged words, as to deceive the officials of the Patent Office into the belief that patentable novelty could really be found in their devices. Among American patents of this class which have sprung up amid a grand flourish of trumpets, and which have been "tried, weighed in the balance, and found wanting," may be mentioned those of Sanders, Gwynne, Elmer, Thompson, and a host of others.

An erroneous idea which has prevailed to a great extent—that by admitting nascent hydrogen into a retort where hydro-carbon vapors are being evolved would result in forming rich permanent gases—has formed the basis of the greater part of these water-gas patents. Because coal tar consists of hydro-carbons in which carbon exists in large proportions, it has been assumed that a union of these tar vapors with hydrogen might be brought about, and the important object of economy largely subserved. In chase of this phantom large amounts of money have been squandered, and although many of these innovations have been subjected to thoroughly impartial tests, and every facility extended to ascertain the truth, they have all of them been found worthless and consigned to a merited obscurity. As one of our most experienced gas chemists justly remarks: "In gas coal nature has placed the constituents necessary to yield all the advantages which the application of water-gas may possess. Water is one of the products of carbonization, but that fact has probably been overlooked by some of our engineers, because it is called in hand-books ammonical liquor. Why should that water which is present in excess, and which is produced from the very coal itself in the form of steam, or even superheated steam if you please, in the presence of tar vapors, and finely divided carbon, and which is in the nascent state if ever anything was so—why should it not, without any additional expense, be decomposed in the same manner as when you pass it into a separate retort, over red-hot charcoal, or coke, or anthracite coal, or iron turnings, or even zinc?"*

In Great Britain and Ireland, gas works are much more numerous than in this country. Almost every small village of a thousand inhabitants is lighted with gas. In 1860 the total number of companies in the United Kingdom was 1,015, distributed as follows: England and Wales 810, Scotland 141, Ireland 64. The aggregate capital at that time invested in the business was very nearly $100,000,000. The average price charged to private consumers was about $1.80 per 1,000 cubic ft., with discounts made to large customers ranging from 5 to 30 per cent. Compared with the charges made by our American gas companies, this rate seems very low; but it must be remembered that labor, and consequently coal, iron, and all other essentials are far cheaper than on this side of the Atlantic.

In the whole territory of the United States there are not 500 gas-light companies. The last accurate tables we have been enabled to obtain were compiled from official sources in 1863, and the number then returned was 433. At that time the price charged to consumers per 1,000 cubic ft. ranged from $1.50 at Pittsburg, to $12.50 at Marysville, California. In this country, as in England, gas companies are usually private corporations, the exceptions to this rule being Philadelphia, Alexandria, Richmond, Va., and Frankfort, Ky., where the gas works are owned and operated by municipal authorities, or by trustees to whom their management is delegated. In considering the question whether it is more desirable for the consumer to be dependent on a municipal or a private corporation, opinions are divided; but experience has proved that there is little if any difference in the practical results; and that if

* Dr. John Torrey.

there is any difference, it is not in favor of municipal management. In all cases the same rules of selling gas are observed; the same meters are used, and the same apparently arbitrary methods of treating delinquent consumers, or their successors, are followed.

Gas companies are always made the target at which are aimed the shafts of indignant consumers; and no matter whether these are served by city works or by private corporations, the result is always the same. But whatever plan of dispensing illuminating gas may be pursued, the advantages of this over every other form of artificial illumination must be conceded. Its cleanliness, safety and economy are universally recognized; and were we compelled to undergo the deprivation of some of the essential comforts to which we have become accustomed, one of the last necessaries we would voluntarily relinquish would be illuminating gas.

CHEMICAL PHENOMENA OF IRON SMELTING.—SOME OF THE CONDITIONS WHICH APPARENTLY AFFECT THE QUALITY OF THE IRON.

By Mr. I. LOWTHIAN BELL.

From "The Journal of the Iron and Steel Institute."

Unlike other metallurgical operations for obtaining a metal from its ores, the iron blast furnace delivers its product of different qualities, well known as foundry and forge iron. The former embraces the dark gray, in crystals, designated Nos. 1, 2, 3, and Foundry No. 4, the color becoming lighter and the crystals smaller as we descend in the scale. Forge iron commences where the foundry ceases, and includes forge No. 4, mottled and white. As is well known, however, to manufacturers, very gray iron is frequently used in the forge, and sometimes, for particular purposes, the forge qualities are required in the foundry. As a rule, a furnace is especially devoted at certain times to the production of a particular quality of metal, this being done by using a smaller quantity of ore, on a given weight of fuel, when foundry iron is sought for, than when forge iron is the object in view.

It may be inferred from this mode of treatment that, for the higher numbers, beginning at No. 1, a more intense temperature is necessary than for the lower, and in consequence of this greater heat, it is not unlikely there may also be some change in the chemical constitution of the product. As regards the first of these suppositions, there can be no doubt that a given quantity of fuel, having a reduced amount of duty imposed upon it, must perform that duty at a correspondingly increased temperature, and this view is confirmed by actual observation. With respect to the second, an opinion is prevalent that the "richer" the iron, as it is called, *i. e.* the nearer it approaches to No. 1, the more carbon has it taken up, and the greater is the proportion of this carbon in the uncombined or graphitic state.

I propose to examine these two questions in the present section.

I believe it will be generally admitted, that if a furnace were working steadily with Cleveland stone, on rich foundry iron, say, half No. 1 and half No. 3, equal to average of No. 2, an addition of 1½ cwt. of mine to the burden carried by 1 ton of coke, would suffice to lower the quality to an average of No. 4, or about two numbers below its former mark. This addition is equivalent to reducing the consumption of coke about .8 cwt. per ton of iron. Assuming that in each case all the CO_2 generated by the action of the ore on the CO, escapes as such, this weight, .8 cwt. of fuel, burnt with hot blast, will all escape at CO, and represent about 2,400 units. If this be correct, then each number, as we ascend in the scale, will require for its production, probably, about 1,200 units, or something like .4 cwt. more coke than the number under it.

I was very anxious to determine, by actual experiment, the difference of temperature in a furnace while running different qualities of iron, and this I endeavored to do by ascertaining the heat of the slag.

Several attempts were made to get this by introducing into an ordinary calorimeter, containing ice, a given weight of slag, as it ran from the furnace, and judging of the temperature by the quantity of ice which was melted. The numbers obtained were as follows :—

					Grammes.
Exp. 632.	Ice melted	per gramme	of slag	....	7.01
" 633.	do.	do.	do.	....	6.88
" 634.	do.	do.	do.	....	8.09
" 635.	do.	do.	do.	....	7.51
" 636.	do.	do.	do.	....	6.70
Average				....	7.238

The variation is from 6.70 × 79 calories=..529 calories.
to 8.09 × 79 " =..639 "

Average........................ 584

The want of uniformity in these experiments with the ice calorimeter, arising chiefly from a varying quantity of ice melting in the external chamber, induced me to try a different plan. A copper vessel, having a capacity of about 12 litres, was surrounded by an outer one, forming a hermetically closed air space. The whole was enclosed in a wooden case, to lessen the loss from radiation, etc. Ten litres of water of a known temperature were poured into the inner vessel, and kept in readiness close to the current of slag, the temperature of which had to be ascertained. A cast-iron crucible, of a tapering form, capable of holding about 200 grammes was placed in one of earthenware to prevent loss of heat. A quantity of the slag was poured rapidly into the iron crucible, and a lid, luted with tempered clay, was pressed into it so as to exclude the water when the whole was immersed in the ten litres of water. As five minutes elapsed before the water ceased rising in temperature, experiments were made to determine the loss during this delay, which was ascertained to amount to 4.04 per cent.

The highest number obtained in this way was 504 calories per unit of slag, which is about 9 per cent. below that of M. Vathaire, possibly owing to loss of heat in transferring the slag to the crucible and the crucible to the water. Occasionally, the number was 40 calories below this, and this often, when the experiment was the most expeditiously performed, which induces me to think that, in the hearth of the furnace itself, there are irregularities of temperature, occasioned probably by changes in the quantity of fuel compared with the ore, arriving at the tuyeres. At any rate, the fluctuations were too great to render it easy to determine the difference in temperature of a furnace making different qualities of iron.

Exp. 637. At one of the Clarence furnaces, which had been working for some time steadily on No. 4 iron, the temperature of the blast was purposely lowered, so that something like 800 calories less per ton of iron entered the furnace. The iron fell to mottled and some white iron while the change was continued, but returned to No. 4, soon after raising the temperature of the air to its former pitch.

Being desirous of knowing whether the temperature of the escaping gases afforded any indication of what was going on in the hearth, two of the Clarence furnaces (capacity 25,500 cubic ft.), and both working on the same burden of minerals, were experimented upon for periods of six to seven hours, upon different days. The temperatures were taken every ten minutes, by means of the electric pyrometer.

No. 4 furnace, making

No. 2. iron. Temp. of gases.	No. 3 iron. Temp. of gases.	No. 4 iron. Temp. of gases.
345° C. (653 F.)	335° C. (635 F.)	343° C. (650 F.)
	334° C. (633 F.)	

No. 5 furnace, making

No. 3 iron. Temp. of gases.	No. 4 iron. Temp. of gases.
363° C. (685 F.)	347° C. (656 F.)
342° C. (648 F.)	
376° C (709 F.)	

From these figures which give 345 deg. C. (653 deg. Fahr.) for No. 2 iron, an average of 350 deg. C. (630 deg. Fahr.) for No. 3, and 345 deg. C. (653 deg. Fahr.) for No. 4, it may be concluded that any excess of heat evolved during the production of the higher number was absorbed and carried away by the iron and slag, because there is practically no difference in the temperature of the escaping gases. In all probability, also, there would be somewhat less heat generated in making the lower quality of iron, most likely due to alterations in the quality of the coke itself.

Repeated allusion has been made, in previous portions of this work, to the complex nature of the action of the blast furnace, and how readily its progress is interfered with by irregularities in the quality of the materials, by want of care in charging, by alterations in the temperature of the blast, or even by changes in the atmosphere, and that these irregularities might amount to fully 5 per cent. on the fuel consumed, or even more. Nothing, therefore, is more easy to comprehend, than that a furnace making any given quality of iron, should slip down a number, or the reverse, when it is remembered that about one-fourth of this 5 per cent. suffices to cause the change.

As a rule, I have assumed, in my estimates of the standard of heat appropriation, that No. 3 iron was being produced; this quality, or from that to No. 3.5, being the usual average run from the furnaces in the vicinity of Middlesbrough.

I am aware my figures have been objected to by some of my fellow ironmasters, whose word is beyond dispute, and for whose experience and knowledge I entertain the highest respect. I believe these discrepancies may often, if not always, arise from a difference of the circumstances under which the furnaces are worked. Thus, supposing a manufacturer required a large quantity of foundry iron, say Nos. 1 and 3, it would be necessary for him to work with such a burden as would insure a margin of heat which would cover all the contingencies I have mentioned, and even then he might receive as much No. 4 as would reduce the average to No. 3. On the other hand, a second maker holds orders chiefly for No. 4, and his furnaces are burdened accordingly, but owing to a combination of favorable conditions, he produces, over some days, nothing but No. 3 iron, which he, of course, will do with a consumption of fuel which will contrast very favorably with that of his neighbor, who is bound to furnish his customers with richer iron in the face of adverse conditions.

Before concluding this section, further proof wiil be adduced of the influence of temperature in determining the quality of iron from the blast furnace; but before giving this, it will be convenient to consider whether the application of this additional heat changes the chemical composition of the metal when it changes its quality in point of richness.

To determine this, a great number of analyses by the processes already described were made of iron of all numbers, of which the following are examples:

Quality of the Iron.	Exp. 638. Clarence. No. 1.	Exp. 639. Clarence No. 1.	Exp. 640. Clarence No. 1.
Fe, by difference	92 913	72 288	92.601
P	1.502	1.174	1.338
S	.071	.055	.063
Si	1.683	1 585	1.634
C uncombined	2 282	2.722	2 502
C combined	.789	1.149	969
Slag	.760	1 027	893
	100.000	100.000	100.000
Total carbon....	3.071	3.871	3.471

Quality of the iron.	Exp. 641. Clarence. No. 3.	Exp. 642. Clarence No. 4.	Exp. 643. Clarence. No. 4.
Fe, by difference	92.550	93 003	92.422
P	1.570	1.480	1 676
S	.108	.072	.023
Si	1 372	1.531	1.353
C uncombined	2.758	2.504	2 686
C combined	.722	.790	.920
Slag	.920	.620	.920
	100.000	100.000	100 000
Total carbon....	3.480	3.294	3.606

Quality of the iron.	Exp. 644. Clarence White.	Exp. 645. Clarence White.	Exp. 646. Wear White.
Fe, by difference	93.181	94.104	90 908
P	1.318	1.134	1.554
S	.199	.016	.209
Si	.640	.900	2.025
C uncombined	2.209	2 472	2.539
C combined	.993	1 014	.745
Slag	1.460	360	2.020
	100 000	100.000	100.000
Total carbon....	3.202	3.486	3.284

If these figures are to be relied on, it cannot be pretended that carbon, either by greater quantity, or by any peculiarity of form, is the cause of the difference between white, and other kinds of iron; for there is to be found among the above, one case of No. 1 pig (Exp. 638) having 3.071 per cent., of which 2.282 is graphitic, against 3.284 per cent., of which 2.539 is graphitic (Exp. 646), in a sample of white iron. If, again, any other substance, found in the above specimens, is examined, it will be observed that there is no feature connected with its presence, to which we can ascribe the variations in quality.

The inference I would draw from the

information afforded by these analyses is, that the condition of iron in respect to its so-called "richness" is, within certain limits, entirely independent of its chemical constitution. The assertion just made is not unreserved, because it is generally thought that an excess of sulphur greatly *hardens* iron, reducing it to the lower numbers, and ultimately converting it into "mottled," or even "white." The second inference to be drawn from what has preceded, is, that if the composition of the iron does not affect its quality, there is no alternative but to conclude that the change is due to alterations of temperature alone. Corroborative of this opinion is the well-known behavior of iron when suddenly cooled, by which even the richest iron, when run into a *chill*, becomes white; and, again, No. 1 iron, if run slowly from the blast furnace, may be reduced in physical appearance to No. 3.

It would appear, judging from the above analyses of Cleveland iron, that the metal, on being fused in the blast furnace, takes up a quantity of carbon, varying from a trifle above 3 to a trifle under 4 per cent., and that the actual quantity does not appear to exercise any influence in determining the nature of the product.

In the fluid state, I conceive the carbon, so taken up, confers upon the iron the property of fusion much below the temperature at which the pure metal melts, and the carbon itself may be regarded as dissolved in the iron. If, during the process of manufacture, the pig metal has been formed at a low temperature, consolidation, I imagine, takes place under such circumstances that the crystals are so minute, and the carbon which is separated assumes the uncombined or graphitic form in particles so minute as to be invisible, and in consequence, the iron is white. If, on the other hand, the furnace is working at a very high temperature, the intensely heated iron crystallizes with large facets, upon which the extruded carbon assumes the condition of distinct plates or flakes.* Should the temperature be less intense, these crystals are of smaller dimensions, and the separated carbon is less conspicuous, and, as the temperature of the furnace declines, the crystals decrease in size, as do the flakes of carbon, until both disappear in white iron.

* A very interesting paper, on the occurrence of graphite in cast iron, was read by Mr. G. J. Snelus, of Dowlais. In it, the author states that, by mere mechanical means, a considerable quantity of carbon in this form was separated from the iron.

Exp. 647. I endeavored to prove the correctness of this view by direct observation on the blast furnace itself. The immediate vicinity of the tuyeres is, of course, the focus of greatest heat, which diminishes rapidly in intensity at a very short distance higher up in the furnace. At a point about 6 ft. above where the blast is admitted, the heat is one of very bright redness, almost white, and certainly quite enough to melt cast iron. I expected some of the iron would be fused at this locality, and, not having encountered the highest temperature of the hearth, would be white. A hole was drilled 6 ft. above the tuyeres in the side of the Wear furnace; some lbs. of fluid iron ran out, all of which was perfectly white, although the produce from the ordinary tapping hole upon the occasion of the experiment, was foundry gray No. 3.

Anyone with the slightest acquaintance with an iron furnace is aware that if the burden of mine is raised beyond a certain point, the slag acquires a black color, deepening in intensity as the excess of ore is increased. This is simply due to unreduced oxide of iron passing into the slag; and, being desirous of knowing whether the presence of a greater or less quantity of this oxide affected the quality of the iron, I had a number of analyses of slag made while the Clarence and Wear furnaces were working on known qualities of iron.

When running No. 1 iron, the slag contained of Fe per cent.:—

Exp. 648.	Exp. 649.	Exp. 650.	Exp. 651.
.71	1.06	.89	.44
Exp. 652.	Exp. 653.	Exp. 654.	Average.
.28	.27	.52	.59

When running No. 3 iron, the slag contained of Fe per cent.:

Exp. 655.	Exp. 666.	Average.
.84	.33	.58

When running No. 4 iron, the slag contained of Fe per cent.:

Exp. 667.	Exp. 668	Exp. 669.	Exp. 670.
.54	.47	.69	.58
Exp. 671.	Exp. 672.	Exp. 673.	Average.
.47	.81	1.00	.65

There is obviously nothing in these numbers to connect the nature of the product with the quantity of iron in the slag.

Returning, then, to the temperature as the cause of differences in quality of pig iron, the "chilling" of gray metal, and its conversion into white, may be regarded as the effect of preventing, by rapid cooling, the formation of crystals sufficient in size to render their coating of carbon visible.

If a quantity of this white iron is introduced in a cupola, as soon as it is heated to its melting point it fuses, and runs to the bottom of the furnace. On being run out, it solidifies under conditions even less favorable for visible carbon separation than when it was produced in the blast furnace; inasmuch as the temperature of a cupola is below that employed for smelting iron. As might be expected, the iron is still white, at all events when run into masses of moderate size.

If, however, such dimensions are given to the fused mass as to produce very slow cooling, then, in spite of the comparative lowness of temperature, the crystals assume a size which permits separation of carbon in a visible form, and in consequence the iron becomes more or less gray in color.

To prove this, I had a mould made, being a cube of 3 ft., and, therefore, capable of holding 5 or 6 tons of metal. The mould was dried and warmed, and into it was run this quantity of white iron. The whole was then covered up with sand to retain the heat as long as possible. At the end of some days the iron was removed, and by means of a heavy weight falling on a steel wedge placed in a cavity cast to receive it, the block, with one blow was split through the middle.

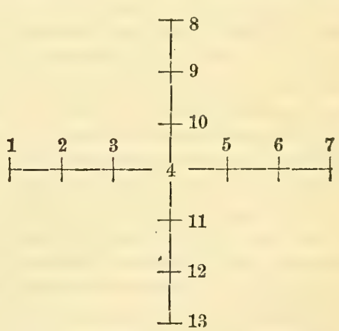
The edges of this fractured surface were white, with a few circular patches of gray; these increased as the centre was approached, and at a distance of 2 or 3 in. from the outside, the color was gray interspersed with patches of white, so that at a little distance it resembled gray granite. One *git* or pouring place, which fed from the bottom upwards, was gray forge at its lower end. Another *git*, which filled an orifice made to permit the air to escape from the top of the mould, was entirely white.

The following four samples were then analyzed:

	Exp. 674. Original pig.	Exp. 675. White git.	Exp. 676. Gray git.	Exp. 677. Near centre of block mottled.
Uncomb'd car.	2.209	2.198	2.472	2.296
Combined ...	.993	.666	1.014	.644
Phosphorus ..	1.318	1.344	1.134	1.346
Sulphur	.199	.197	.016	.007
Silicon	.640	.860	.900	.760
Slag	1.460	1 020	.360	.920
Iron by differ.	93.181	93.715	94.104	94.027
	100.000	100.000	100.000	100 000
Iron by anal's	92.650	94.250	93.850	94.500
Total carbon	3.202	2.864	3.486	2 940

The chief alteration appears to be, that remelting has removed more or less of the slag. The phosphorus remains the same; the silicon has increased; and the sulphur in the gray and mottled iron, has notably diminished. The carbon is lessened in two of the cases, and increased in the third.

To ascertain whether the decrease of sulphur in Exp. 676 and 677 was not merely accidental, the block had 2 lines drawn at right angles across the centre of the fractured face, and specimens were drilled out at intervals of 6 in., and numbered thus:—



Of these, a certain number were analyzed, and gave the following results:—

Per cent.	Exp. 678 No. 1.	Exp. 679. No. 2.	Exp. 680. No. 4	Exp. 681. No. 5.
S........	.234	.218	.195	.234
C comb..	....	....	.626	720
" uncomb.	....	....	2.046	2.008
Total C .	2.842	2.978	2 672	2.728

Per cent.	Exp. 682 No. 6.	Exp. 683. No. 7.	Exp. 684 No. 8.	Exp. 685. No. 9.
S........	.236	.248	.242	.234
C comb..	.626	.770	....	....
" uncomb.	3.132	2.236	....	....
Total C..	2 738	3.006	2.802	2.776

Per cent	Exp. 686. No. 11.	Exp 687. No. 13.
S	.200	.242
C combined.	....	....
" uncombined...........	....	....
Total C	2.788	3.070

The foregoing experiments were undertaken partly to see whether, as with the Ag and Pb in the case of the Pattinson process of desilverizing lead, any combinations of Fe and those subtances which are associated with it in pig iron, remaining liquid longer than others, might be found to be concentrated in particular portions of the mass.

From these numbers we may regard the whole block as possessing a uniform composition as regards sulphur and carbon.

In order to secure the exposure of some white pig iron to a temperature which was known to suffice for the production of gray, the following trial was made :—

Exp. 688. A furnace running No. 3 iron was selected, and at a point a few feet from the opening where the slag flowed out, a channel and a basin in its course was scooped out in sand, so that when the slag ran down the channel the small reservoir contained a certain quantity in a fluid state. The current was continued long enough to prevent the cold sand materially affecting the temperature of the molten mass, which as usual ran through an external crust. Quite close to where the stream left the furnace, and, therefore, before it had parted with any notable quantity of heat, a bar of white iron was inserted in the current, where it speedily melted, and as the globules of metal dropped off the bar they were carried forward by the slag down the channel until they were intercepted by, and retained in, the basin. In this way they were exposed to heat closely approaching that of the interior of the furnace itself. When a few lbs. were thus carried off, the current was diverted and the iron removed when solid, and found to be No. 3, although not above an inch in thickness.

Exp. 689. A quantity of the iron obtained in the previous experiment was melted in a crucible, and run into a mould having a transverse sectional area of about 1 in., to see whether there was any tendency to re-assume the condition of white iron. It remained perfectly gray, but became closer in the grain; not more so, however, than a specimen of ordinary No. 3 iron, when treated in a similar way.

What the temperature to which this iron was subjected is, I have been unable to determine. One step towards this would have been ascertaining accurately the quantity of heat contained in the liquid contents of the furnace. In this, as has been stated, I have hitherto failed ; but were we in possession of the necessary information, the absence of all data as to the specific heats of bodies at very high temperatures prevents further progress in the estimate.

Exp. 690. The only experiment I performed in the direction indicated, consisted in immersing a piece of bar iron in the slag runner in the manner observed with the white pig iron, the produce of the furnace itself at the time being gray No. 3. It was fused and collected in the basin, still preserving the property of malleability. The melting point of this substance is stated by Daniell to be above 1,800 deg. C. (3,272 deg. F.)*

Kartsen determined that gray iron had a higher melting point than white iron, and mentions that this latter variety might be converted into gray iron by very slow solidification at a high temperature, as well as that gray iron became white on sudden solidification. Dr. Percy† questions the conversion of white into gray iron, under the circumstances described, as a universal law ; but I imagine this difference of opinion may be due to proper precautions as to slowness of cooling not having been observed. So far as my own recollection serves me,

* Daguin (Traité de Physique) gives 1,500 deg. C. as the fusion point of *fer doux*, and 1,600 deg. C. *fer ecroui*, apparently on the authority of Pouillet.

† Percy's Metallurgy, Iron and Steel, p. 112.

this change from gray to white, and a partial change at all events of white to gray (mottled), are facts which were well known to every practical iron-founder long before the date of Karsten's paper containing the opinions quoted above, which was written in 1846.

Gurlt, from reasons founded upon certain supposed definite compounds of iron and combined carbon, conceives grayness and whiteness in iron to be determined by their respective compositions, and mottled to be a mixture of the two. In support of this, he speaks of having converted spiegeleisen containing manganese into gray iron by simple exposure to a temperature much higher than its own melting point. What the nature of the change, if any, may be when the metal is fluid, probably no one can say; but so far as its composition after solidification is concerned it would be difficult to ascribe any change in its physical aspect to any alteration either in its content of carbon or in its chemical constitution. This at least is what may be gathered from the analysis of the pig iron used for the large block described in this section, the different portions of which were stated to contain—

Experiments.	Uncombined carbon.	Combined carbon.	Total.
674. White pig iron before fusion, per cent	2.209	.993	3.202
675. White git after fusion ...	2.198	666	2 864
676. Grey do. do. ...	2.472	1.014	3.486
677. Centre of block do., mottled	2.296	.644	2.940
680. Do. do. do.	2.046	.626	2.672
681. Specimen 6 in. from centre mottled	2.008	.720	2.728
682 Specimen 6 in. from outside, mottled......... ..	2.132	.626	2.758
683. Specimen next outside, nearly white...........	2.236	.770	3.006

According to Gurlt, says Dr. Percy, gray iron is an octocarbide intermingled with graphite, and white iron a tetracarbide. The latter is formed at a low heat, comparatively, and is resolved at a higher temperature into octocarbide and graphite. The Doctor commends Gurlt's theory for its simplicity, but objects to the conclusion which practically makes difference of temperature explain everything.

Unless the numbers indicating the total quantity of carbon in my large cube, as well as those denoting the weight of this ingredient in its so-called combined and uncombined condition, involve a good deal of experimental error, I am disposed to agree with Dr. Percy that it is improbable that the production of one kind of iron depends on the decomposition by temperature of another; but I do feel inclined to adopt the conclusion this author hesitates to consider as founded on truth, viz., that difference of temperature may, and probably does, explain everything.

On the other hand, Karsten, and after him, Janoyer and Percy, appear to have proved that sulphur expels carbon from iron at a high temperature. I have not myself made this question the subject of examination, but I may state it is a matter of belief among practical men that sulphurous coke in the blast furnace, and the use of this kind of fuel in the foundry cupola, so hardens the iron that it is apt to be white towards the edges.

Pig iron, although always containing other matter than iron and carbon, consists essentially of these two elements alone, inasmuch as if perfectly pure Fe_2O_3 is heated with pure C, a substance analogous in character to pig iron is obtained.

The composition of the crude or pig iron of commerce differs, however, considerably from the substance produced under such conditions as those just described, and as the elements other than those previously named, and which may be regarded as impurities, are of course derived from the minerals used, the extent of such contamination will in a great measure depend on the quality of the fuel, ores, and flux employed in the blast furnace.

Although the substances which enter a blast furnace may be, and are, very numerous, it by no means follows that they of necessity find their way into the pig iron. What the circumstances are which determine the absorption of varying quantities of some of them by the metal, our knowledge of the process is at present too limited to pronounce.

Phosphorus, under all circumstances, as we have seen in the previous section, may be assumed as being almost entirely taken up by the iron; whereas sulphur, by the copious use of lime and a high temperature, is almost as completely found in the slag.

Manganese, when a constituent of the ore, is found partly in the iron and partly in the slag. Upon one occasion* when using an admixture of a manganiferous ore, containing 30 per cent. Mn and 17 per cent. Fe, with the Cleveland stone, I found the different qualities of iron contained

	No. 1 pig.	No. 2. pig.	No. 3 pig.
Manganese	1 75	2.31	2 45
Carbon	2.94	2.90	3.30
Sulphur	.292	.247	.254
Phosphorus	.416	.860	.867

The slag produced at the time of the addition of this manganiferous ore contained:

Si	29 25
Al_2O_3	19.25
Ca O	38 25
Mg O	.60
Fe O	1.04
Mn O	8.76
Si	2.16
TiO_2	.75
	100.000

By calculation, it appeared, of 100 parts of manganese which entered the furnace, there was

United with the iron	9 5
Found in the slag	87 6
Unaccounted for	2 9
	100

Of the other foreign ingredients, the only one of importance, either from its almost universal presence in, or its effect on, the iron, is silicon.

In the analyses quoted in the present section, it will be observed Si varies considerably in quantity in the iron smelted from Cleveland stone. It has been pretended that this substance is an essential ingredient in pig iron, but looking at some analyses, and at the fact that cast iron may be produced from carbon and pure iron, there seems no good grounds for the assumption.

With regard to the influence of Si on the quality of pig iron, it may be questioned whether it is ever beneficial. Even in moderate quantities the metal itself is undoubtedly rendered weak as a material for the purposes of the founders, and its presence in any quantity in forge iron is undoubtedly detrimental, inasmuch as it not only yields no malleable iron, but, on the contrary, it carries off a large quantity of Fe as a silicate.

From this somewhat general condemnation, I understand, must be excepted a moderate amount of Si in iron destined for the production of Bessemer steel. Here the heat evolved by the generation of SiO_2 is regarded as helping the process, and may also possibly assist in forming a vehicle by means of which some of the other impurities are removed from the product sought for.

Under these circumstances, viz., that the presence of Si at one time and its absence at another are desirable, it becomes a subject of some interest to inquire what are the conditions which are most conducive to the reduction of SiO_2 and the absorption of its base by the iron.

With the exception of Exp. 646, in which Si appears in excessive quantity in a specimen of white iron, its presence is promoted by a high temperature, which is, as might be expected, favorable to the decomposition of SiO_2, because, as a rule, the "richer" the iron the more Si is there in the pig, and we have seen "richness" is acquired at the expense of heat. Thus the percentage of Si is in—

Making No. 1.		Making No. 3.	
Exp. 638	1.683	Exp. 641	1.372
" 639	1.585		
" 640	1.634		
Average	1.634		1.372

Making No. 4.		Making white.	
Exp. 642	1.531	Exp. 644	.640
" 643	1.352	" 645	.900
Average	1.421		.770

There occurs, however, occasionally, at most ironworks, a state of things which leads to the production of a kind of iron known in the north of England under the name of "glazy metal." This variety of pig is gray in the fracture, somewhat leaden in its aspect, and is composed of small crystals. With these peculiarities well marked, it is scarcely too much to say, the article is almost entirely worthless. In castings it is weak to rottenness, and in the puddling furnace it melts like water, and so completely defies the ex-

* Report to British Association, 1863, I. L. Bell.

ertion of the puddler, that his "fettling" disappears long before the obstinate material he is operating on shows any signs of "coming to nature."

I have known a furnace go upon this quality of iron, and before its condition came to my knowledge, make a couple of hundred tons of this valueless substance. The cause of its appearance is generally considered to be dependent on excessive heat in the furnace—at all events, raising the burden of the ore, or lowering the temperature of the blast, which latter has the advantage of being a readier mode of cure, always puts an end to its production.

Two specimens of glazy iron were analyzed, and found to contain*—

Fe	88.18	90.70	S.........	.17	.23
C combined	.79	.71	P.........	1.12	1 12
C uncomb'd	2.59	2.68	Ti.........	.26	.18
Si.........	5.13	5.13	Ca.........	.22	.20
Mn.........	.77	56	Mg.........	.06	.03
				99.29	101.54

* I. L. Bell: Report to British Association, 1863.

From what has preceded, it seems within our reach to avoid deteriorating the quality of our iron by an excessive amount of Si, by avoiding too high a temperature; but, on the other hand, as the "richer" kinds of iron are dependent for their production on the application of more intense heat than the lower numbers, the same cause which gives us "rich" iron may increase its content of Si, and hence the difficulty of our altogether avoiding the presence of this substance. This is particularly the case in Cleveland iron, which, from what I consider the comparative infusibility of the slag which accompanies its production, requires, in my opinion, a somewhat higher temperature than that demanded in the treatment of more silicious ores. A portion of the silica exists in its combined form in the ore, and this also may promote the readiness with which this constituent is decomposed, and thus account for the somewhat excessive quantity of Si in the pig iron made in the district in question.

STEAM TRAMWAY CARS.

From "The Engineer."

It is indisputable that the tramway system is on the whole successful in London, so successful at least that its extension is simply a question of time. Of course, there are people opposed to tramways who write to the "Times" and tell its readers that the wheels of their broughams are broken, and that their horses are lamed by the grooved iron track laid in some of our metropolitan roads. But tramways are not intended to please the owners of broughams and horses, but an infinitely more numerous class; and the members of this class like the tramways very much indeed, and advocate their extension to districts in which nothing but the omnibus or the cab is now to be found. Successful as the tramway system is, it is nevertheless obvious that it is open to improvement, and it is certain that the improvement will be effected. We shall have better rails better laid, and improved cars, and more comfort, and cheaper fares, and larger dividends for the shareholders; but about the rails, the cars, or the dividends, it is not our purpose to speak at present; instead, we propose to consider the possibility of getting rid of horse labor altogether, and propelling our street tramway cars by steam power. A great deal of misapprehension exists on this subject, which is not confined to the minds of the general public. On the contrary, men who ought to know better have not hesitated to say that the thing is impossible. That this opinion has no sound basis we shall endeavor to show. The principal objections urged against the use of steam on our tramways are, firstly, that it would render the cars a nuisance, because the steam and smoke would escape into the air, and annoy foot passengers, householders, and others; secondly, that the engines would make a great noise; thirdly, that they would frighten horses; and, lastly, that they would be very dangerous. Every one of these objections was urged against the use of steam on railways thirty or forty years ago, but they did not impede the progress of the railway system. We think it can be proved that they would not apply at all to properly constructed steam tramway cars.

The best tramway cars now running in London weigh about 2 tons 5 cwt. empty, but we shall be nearly correct if we take the average weight at 2 tons 10 cwt. Forty passengers may be taken to weigh as much more. We have then a gross load of 5 tons as representing the ordinary net weight to be propelled. An average velocity of 6 miles an hour will meet all requirements, and at this speed the resistance per ton cannot exceed 10 lbs. on a dead level with the rails clean and dry. As, however, the rails are usually anything but clean, and the wheels are small, we shall take the resistance at 20 lbs. per ton, and therefore assume that a dead pull of 100 lbs. will be required to keep a loaded tramway car in motion at the rate of 6 miles an hour on a level. On inclines the resistance will, of course, be increased. On a rise of 1 in 40 the tractive force must reach 380 lbs. while on an incline of 1 in 30, which is the very steepest hill on which a street tramway is, in our opinion, admissible, it must amount to 473 lbs. It is just possible for two good horses to take a tramway car weighing with its load 5 tons up an incline of 1 in 30 at a very moderate pace. Any motive power in the shape of an engine which will exert a tractive force of 100 lbs. per ton will muc more than meet all the requirements of the most difficult case which it is possible to imagine.

Now a velocity of 6 miles an hour is 528 ft. per min., and this multiplied by 100 lbs., gives 52,800 foot-pounds as the work required to take one ton of tramway car up an incline of 1 in 30. We have seen that the net weight of the tram-car and its load would be 5 tons, consequently the total work to be done would be 264,000 foot-pounds per min., or exactly 8 effective horse-power. A suitable steam engine, boiler, etc., will probably weigh 1 ton 10 cwt.; add this to the weight of the loaded car, and we have 6 tons 10 cwt. The additional power required to deal with the weight of the engine amounts to 79,200 foot-pounds, or 2.4 horse power. The indicated horse power ought to exceed the effective by about $\frac{1}{4}$; and, making this allowance, we find as the result of our calculations that the maximum power which can by possibility be required in a street tramway car, propelled by steam, is 13-horse power indicated. An engine and boiler weighing 30 cwt. would, with ease, exert double this power for an hour at a time. We need scarcely state that it is quite within the reach of the most ordinary practice to provide an engine and boiler which shall not weigh more than 30 cwt., and yet will suffice to meet the most extraordinary demands that could be made on its powers of propelling a tramway car. Now let us see how much power would be required under ordinary circumstances. The answer is ready to our hand. Two good horses do the work; and, allowing that each of these animals exerts 75 per cent. of an indicated horse power—which is over the mark—we still find that an engine working up to a little over two indicated horse power, would do all that is generally required. The steam engine fitted to the tramway-car should therefore have cylinders so large that at 6 miles an hour it might exert 13-horse power if a short bit of incline had to be surmounted, as, for example, in crossing a steep bridge; but under ordinary circumstances these cylinders would be worked very expansively by the aid of the link motion. The result would be that the blast would be so far softened that the escaping steam would make little or no noise. Another and most important advantage conferred by the large cylinders would be the power of starting the car rapidly into motion. A speed of 6 miles an hour is 8.8 ft. per sec., and this is very nearly the velocity which would be acquired by the car in falling through a distance of 1 ft. Most of our readers will, we think, understand us when we say that these figures prove that to get the car into motion at the rate of 6 miles an hour 14,560 foot-pounds of energy must be expended over and above the force required to overcome frictional resistance, this 14,560 foot-pounds remaining stored up in the car, to be given out again when it is being brought to rest. If the work of starting the car from a state of rest to one of motion be performed in 10 sec., it follows that during each sec. 1,450 foot-pounds of work must be done, or say, 2.6 horse power. From which it will be seen that on a level the engine should exert about $2\frac{1}{2}$ times more power at starting than will be required when the normal velocity has been attained. All this is perfectly consistent with working conditions. There is not, in a word, the slightest difficulty in designing engines and boilers, which will comply perfectly with the required stipulations as to weight and power. If any proof of the truth of this statement is required, it may be found in the fact that Messrs. Shand and Mason's Light Brigade engine, weighing complete, with carrying wheels, framing, hose-reel, etc., 35 cwt., has indicated 33-horse power with ease. There is no trouble, therefore, in producing an engine and boiler alone weighing more than the fire engine complete, which would, if needful, work up to 13-horse power, while their normal power would not necessarily exceed from 2-horse power to 5-horse power indicated. As regards the nuisance question, we have already shown that the "beat" of the engine would be almost entirely got rid of. It would be quite removed by turning the waste steam into a large cast-iron hollow deflector, as is done in Field boilers, from which it would escape continuously, highly superheated and completely invisible. If good selected coke was used as fuel, no one in the street or in the car need be aware that a steam engine was used at all. In proof of this statement we may refer to Messrs. Moreland's steam rollers, in which the waste steam is superheated as we have described. Nothing whatever can be seen coming from the chimney, even when the engine is working to its greatest power.

The danger theory does not deserve a word of refutation, in so far as it refers to the chance of accident to those within or upon the cars, caused by a failure of the boiler or machinery. As regards the chance of accident by collision, that is purely a question of brake power. To stop the car would require precisely the same expenditure of energy as was needed to impart a velocity of 6 miles an hour —or, in other words, 14,560 foot-pounds. The co-efficient of friction on a tram rail —which is always more or less gritty— cannot be much less than 1-6 of the load. The load in the case we are considering is 6.5 tons, or 14,560 lbs., and 1-6 of this is 2,426.6 lbs. Each foot therefore traversed by the vehicle with the brakes hard on will represent 2,426 foot-pounds of energy expended in overcoming the friction between wheel and rail, in round numbers, and dividing 14,560 by this, we find that the car can be stopped on a level in a space of about 6 ft., which is less than that in which an existing car or a common omnibus can be pulled up. With common care on the part of the driver no accident whatever could occur from collisions.

We believe that we have made out a good case so far as we have gone for the steam-propelled omnibus, although we have not said a syllable concerning the advantages it holds out to shareholders and others. These and one or two other points we shall probably deal with in future articles.

THE BRITISH COAL COMMISSIONERS' REPORT.

From the "Quarterly Journal of Science."

The question which gave rise to the appointment of the Royal Commission, whose Report* we are now about to review —namely, the probable duration of the coal resources of the United Kingdom— was, according to Mr. Jevon's account,† first raised by one John Williams, a mineral surveyor, who, in a work published by him in 1789, entitled "Natural History of the Mineral Kingdom," gave a chapter to the consideration of "The Limited Quantity of Coal of Britain." At that time the coal production of the United Kingdom amounted only to about 7,500,000 tons annually. This subject was also referred to by Sir John Sinclair, in his "Statistical Account of Scotland," and again in 1812, by Robert Bald, in his "General View of the Coal Trade of Scotland." Later still, Dr. Buckland prominently brought it before the public, both in his evidence before the Parliamentary Committees of 1830 and 1835, in his "Bridgewater Treatise," and again in his address to the Geological Society, on the 19th of February, 1841. Up to this time, however, the public generally did not express any great interest in the matter; and it was not until the publication of Mr.

* Report of the Commission to Inquire into the several Matters relative to Coal in the United Kingdom, July 27, 1871.

† The Coal Question: an Inquiry concerning the Progress of the Nation, and the Probable Exhaustion of our Coal Mines. By W. STANLEY JEVONS, M. A., etc. 1866.

Hull's work* on the subject, in 1861, that its real importance began to be better appreciated. This was shortly afterwards followed by Sir William Armstrong's celebrated address as President of the British Association, at Newcastle, on the 26th of August, 1863, in which he stated that "the entire quantity of available coal existing in these islands has been calculated to amount to about 80,000 millions of tons, which, at the present rate of consumption, would be exhausted in 930 years; but, with a continued increase of $2\frac{3}{4}$ millions of tons, would only last 212 years." This anouncement, by which the real importance of the question was put before the public in a practical shape, caused at the time considerable excitement throughout the country; and it soon became clear that some confirmation or refutation of the statistics first published by Mr. Hull in his work above referred to, and subsequently promulgated by Sir William Armstrong, was desirable in the public interest. On the 12th June, 1866, the subject was brought before the House of Commons, by Mr. Hussey Vivian, in a very able speech, in which he moved for the appointment of a Royal Commission to inquire into several questions connected with the coal resources of the United Kingdom. This motion was agreed to, and on the 28th idem, the Commission was accordingly appointed, consisting of fifteen members,† with the Duke of Argyll as Chairman.

The special instructions to the Royal Commission were as follows :—

"To investigate the probable quantity of coal contained in the coal-fields of the United Kingdom, and to report on the quantity of such coal which may be reasonably expected to be available for use.

"Whether it is probable that coal exists at workable depths under the permian, new red sandstone, and other superincumbent strata.

"To inquire as to the quantity of coal at present consumed in the various branches of manufacture, for steam navigation, and for domestic purposes, as well as the quantity exported, and how far and to what extent such consumption and export may be expected to increase.

"And whether there is reason to believe that coal is wasted by bad working, or by carelessness, or neglect of proper appliances for its economical consumption."

The first act of the Commissioners was to form amongst themselves five committees for the following purposes:—

1. A. Committee on possible depths of working.
2. B. Committee on waste in combustion.
3. C. Committee on waste in working.
4. D. Committee on the probability of finding coal under permian, new red sandstone, and other superincumbent strata.
5. E. Committee on mineral statistics.

Without confining ourselves in any way to the order in which these Committees subdivided the several questions submitted for their investigation, we now proceed to give briefly the results arrived at by them, and which have been embodied in their respective reports, or brought out in the evidence taken by them.

There is but little reason for doubting that British coal was used in small quantities in the days of the Roman occupation of these islands, as it has been found amidst the remains of Roman civilization in the city of Uriconium and elsewhere. Statements respecting the use of coal before the twelfth century are, however, exceedingly fragmentary; since that period there is tolerably ample information to be obtained respecting the coal trade from the rivers Tyne and Wear, but very little relative to the production at this period of coal in other parts of the kingdom. The first record dates back to the year 1180, when Bishop Pudsey, of Durham, granted some land to a collier, to provide coals for a smith at Coundon, in the county of Durham; similar grants being also made at Sedgefield and Bishop-Wearmouth. In 1213, a charter was granted by King John to the men of Newcastle to dig coal. The earliest record of coal being used in the south of England is in 1279, when coal was purchased at Dover for the use of the Castle. In the year 1300 coal was used in quantity by the brewers and smiths of London; which was, however, prohibited in 1306, on the ground of its being an intolerable nuisance, but fifteen years after-

* The Coal Fields of Great Britain. By EDWARD HULL, B. A. 1861.

† Sir R. J. Murchison, Sir W. G. Armstrong, Messrs. H. H. Vivian, G. T. Clark, J. Dickinson, G. Elliott, T. E. Forster, J. Geddes, R. Hunt, J. B. Jukes, J. Hartley, J. Percy, J. Prestwich, A. C. Ramsay, and J. T. Woodhouse.

afterwards it was used in the Royal Palace. The first Government tax was laid on coal as early as 1379, amounting to twopence for every chalder;* but in the reign of Elizabeth it was raised to twelvepence per chalder, which was regularly enforced to the time of Charles II. Duties were laid on sea-borne coal to assist in building St. Paul's church and fifty parish churches after the great fire of London; and in 1677, Charles II. granted to his natural son, Charles Lennox, Duke of Richmond, and his heirs, a duty of one shilling a chaldron on coals, which continued in the family until it was purchased by Government in 1799, for the sum of £400,000. This impost was known as the "Richmond shilling," and produced soon after it came into the hands of the Government £25,000 a year.

The practice of coal mining had arrived at such a degree of importance at the beginning of the eighteenth century, that we find treatises published as guides to the system of exploration. Many of the collieries were then extensive, and accidents were not unfrequent. An account is given by one author† of a "blast" which occurred in October, 1705, when "there were above 30 persons, young and old, slain by a blast, perhaps in less than a minute's time."

In 1771 there was formed a combination among the coal owners who shipped their coal by the three rivers, the Tyne, the Wear, and the Tees, to raise the price of coals to consumers by restricting the quantity supplied. This combination, known as the "limitation of the vend," lasted with, but a few temporary interruptions, until 1845. As this restriction did not apply to coal shipped to foreign parts, it frequently happened that coal was sold to foreign markets at 40 per cent. under the prices in the London market. About 1791 a feeling grew up in favor of obtaining coal from the midland and other coal-producing counties for the London market.

Coal was first worked in Cumberland, at Whitehaven, by Sir John Lowther in 1660, but there does not appear to exist any record of the quantity raised until towards the end of the 18th century. Little appears to be now known of the early history of the Lancashire coal-fields. In the Cheshire coal-field, coal is said to have been first opened in Nerse township in 1750. The early history of coal mining in Yorkshire is very obscure ; but it is stated in an early number of the "Leeds Intelligencer," a local newspaper, that in 1752 a petition was prepared for Parliament for rendering the Calder navigable, the chief object being the conveyance of coal. The Derbyshire coal-fields are referred to by Pilkington,* who wrote in 1789; and Cambden, in his "Natural History of Warwickshire," A. D. 1730, was perhaps the first to record any facts relative to what is known as the Staffordshire coal district. Shropshire from a very early period appears to have yielded from its stores fuel for the use of man. Shropshire coal has been found in the ruins of Uriconium. The earliest record of any colliery workings in this county, however, appears in the "Leeds Intelligencer" for November 23d, 1756. The first notice of the production of coal in the Forest of Dean appears to be supplied by the records of the Justice Seat held at Gloucester in 1282, where it is stated that sea coal was claimed by 6 of the 10 bailiffs of the Forest of Dean. Coal was sent to London from South Wales as early as 1745, and in North Wales the Mostyn Collieries date from the 23d year of the reign of Edward I. Amongst the earliest reliable accounts of the Scotch coal-field, we find that in the 12th century, William de Vetereponte granted to the monks of Holyrood, "totam decimam de carbonaris meo de Carriden." This is the name of a small brook flowing into the Frith of Forth, about 3 miles north of the ancient palace of Linlithgow. This was in the time of William the Lion, during whose reign the monks of Newbattle worked coal on the margin of the Esk. Arthur Dobbs, author of an "Essay on the Trade of Ireland," writing in 1728, says, "We have of late discovered coal mines in the counties of Cork and Leitrim."

Having thus, in the briefest possible manner, touched upon the early history of the coal-fields of the United Kingdom, we pass on now to notice the amount of coal

* This was probably the Newcastle chalder, containing 53 cwts. of coal.

† The Compleat Collier; or, the whole art of Mining and Working Coal Mines, etc., as is now used in the Northern Parts, especially about Sunderland and Newcastle. 1708.

* A view of the present state of Derbyshire with an account of its most Remarkable Antiquities, etc. By James Pilkington. Derby, 1789.

that has been raised from time to time. The estimated production of the whole Kingdom is thus given in the Commissioners' Report :—

"In the 3 centuries before 1800, it is computed that not less than 850,000,000 tons of coals were raised from the coal-fields of the kingdom. During the next 50 years there was a constant and steady increase in the production, and fully two thousand millions of tons of coal were extracted. Up to this time the records of coal produce were most imperfect and it was not until the year 1854 that reliable returns have been in existence. The average production in 1851, 1852, and 1853, may be taken at 50,875,000 tons per annum. In the years 1854 to 1869, both inclusive, 1,343,793,705 tons were raised, which, added to the figures above given, and estimating the return for 1870 at 110,000,000 tons, show that we have already drawn from our original stores of fuel not less than 4,456,000,000 tons* of fuel."

Space will not admit of our entering into any minute detail regarding the consumption of coal, but it may be stated that, of the 107½ millions of tons raised in 1869, 32,446,506 tons were employed in iron manufacture ; 25,327,213 tons in manufactures; 3,277,562 for steam navigation; 2,027,500 for railways, locomotives, etc.; 18,481,572 in domestic consumption; and 9,775,470 tons were exported.

Large portions of some of our coal-fields lie at a greater depth than has yet been reached in mining, and it is considered that the increase in temperature which accompanies increase of depth is the only cause which it is necessary to consider as limiting the depths at which it may be practicable to work coal. In this country the temperature of the earth is constant at a depth of about 50 ft., and at that depth the temperature is 50 deg. F. The rate of increase of the temperature of the strata in the coal districts of England is in general about 1 deg. of Fahrenheit for every 60 ft. of depth. The depth at which the temperature of the earth would amount to blood heat, or 98 deg., is about 3,000 ft. Under the long wall system of working, a difference of about 7 deg. appears to exist between the temperature of the air and that of the strata at the working faces, and this difference represents a further depth of 420 ft.; so that the depth at which the temperature of the air would, under present conditions, become equal to the heat of the blood, would be about 3,420 ft. Beyond this point the considerations affecting increase of depth and temperature become so speculative as to render it necessary to leave the question in uncertainty ; but, looking to possible expedients which the future may elicit for reducing the temperature, it is considered that it may fairly be assumed that a depth of at least 4,000 ft. might be reached.

Before considering the supplies of coal which still remain for consumption, within a workable depth, it is necessary to refer briefly to the waste that now occurs in working, and through imperfect combustion.

The theoretical value of 1 lb. of coal is 14,000 units of heat, which, if properly applied, should be equal to the power of lifting 10,800,000 lbs. 1 foot high, whilst the highest practical result which has been realized is 1,200,000 lbs., or less than one-eighth of the theoretic value, and this without counting the impurities of ordinary coal, which cannot be taken at less than 10 per cent. *Theoretically*, 1 lb. of pure coal should evaporate about 13 lbs. of water ; *practically*, 1 lb. of ordinary coal does not evaporate 4 lbs. The best results are stated to have been obtained in the boilers of Cornish engines, or in boilers constructed upon the model of the "Cornish boiler." The "duty" of the best Cornish engines since 1814 shows that, up to a certain point, there was a gradual increase in the number of pounds lifted 1 ft. high by the combustion of 1 bushel (94 lbs.) in the earlier tables, and of 1 cwt. (112 lbs.) in the latter ones ; and that, after the maximum had been obtained, there was a steady decline in the effective power obtained ; but the highest recorded duty is about 98,300,000, in 1857. Upon the general question of coal consuption, the conclusion arrived at by the Commission is that "for some time past, in our manufactures, there have been constant and persevering efforts to economize coal, by the application of improved appliances," and there is reason to believe that, "in some branches of manufacture, the limits of a beneficial economy appear to have been nearly

* The Report says 4,300 millions of tons, but in this figure the returns for the 3 years 1851 to 1853 appear to have been omitted.

reached, and that in other cases a gradual effort would continue to be made for saving fuel." It may be assumed, therefore, that the progress of economy in using coal is not likely to operate in future with greater effort in keeping down the increase of consumption than it has hitherto done. The present consumption of coal for domestic use is generally estimated at 1 ton per head of the whole population, and the future increase under this head may be expected to coincide with the increase of population; whilst, as regards the future exportation of coal, there is reason to doubt whether much further increase will take place in this direction, owing to the steady development of the coal-fields in other countries.

With regard to the available supplies of fuel yet remaining, a not unimportant consideration is the amount of waste incident to mining coal. It is clear from the evidence adduced on this subject, that, although in many instances waste in working is reduced to a minimum, and although manifest improvement is being made in the working of coal, especially by the extension of the system of "long wall," nevertheless coal is wasted by bad working and by carelessness, and that to a very considerable amount in proportion to what is actually used. Under favorable systems of working the loss is about 10 per cent., while, in a very large number of instances, the ordinary waste and loss amounts to 40 per cent., irrespective of what is sacrificed by the necessity for leaving coal for barriers, for the support of buildings, and for other objects. This is a very considerable evil, and one which requires immediate attention. If it be necessary to husband our coal resources, means should be everywhere encouraged, not only for the introduction of an improved system of getting coal, so as to reduce the waste to a minimum, but for the better utilization of small coal, none of which should be permitted to be left below that can possibly be raised. One method of utilizing small coal, which is briefly referred to by Committee E in their Report, is by the manufacture of patent fuel; but this is not at present carried on to a sufficient extent to have much effect upon the general question.

In considering the quantity of coal in known coal-fields, 4,000 ft. has been adopted as the limit of practicable depth in working, and a certain proportion has been allowed for waste and loss incident to working the coal. With these provisions, the estimated quantity of coal in the ascertained coal-fields of the United Kingdom is 90,207 millions of tons, whilst at depths below 4,000 ft. it is computed that there is a further supply amounting to 7,320 millions of tons, which might be obtained if existing obstacles to working at a lower depth than 4,000 ft. were overcome. Space will not admit of our even touching on the considerations upon which the Commissioners express themselves in favor of finding coal under the permian and newer strata. The supply from this source, within the depth of 4,000 ft., is roughly estimated at 56,273 millions of tons. It is considered probable that coal measures may possibly extend beneath the south-eastern part of England; but Sir Roderick Murchison contends, in opposition to this theory, that "in consequence of the extension of Silurian and Cambrian rocks beneath the secondary strata of the south-east of England, and of the great amount of denudation which the carboniferous rocks had undergone over the area of the south of England previous to the deposition of the secondary formations, little coal could be expected to remain under the cretaceous rocks." As this question is still one of theory, no attempt has been made by the Commission to estimate the quantity of coal lying under the unexplored area of the south of England.

Omitting the probable amount of coal below 4,000 ft. in depth, there thus appears to be an aggregate quantity of 146,480 millions of tons which may be reasonably expected to be available for use; and it remains now only to see how long that quantity, with an increasing consumption, is likely to last. The bases upon which calculation may be made, as to the probable duration of our coal supplies, are numerous, and varying conclusions have been consequently arrived at by different authorities. The two great principles upon which such a calculation should be based are—the annual increase in population, coupled with the increase in consumption of coal per head of the population. Now from the year 1811 to 1821 the increase in population was 16 per cent., while in the last decade, from 1861 to 1871, it was $11\frac{3}{4}$ per cent. These two rates of increase, in conjunction with those of the intervening decades, have been taken as the elements of a curve, which, carried forward, shows the extent of the population in future years, supposing no disturbing causes to arise. The rate of consumption of coal per head of the population appears to have been very irregular; but, on an average, the increase in fourteen years amounts to nearly 3 per cent. per annum, but it is not thought probable that this rate will be maintained. From statistical tables furnished by the Commissoners, it appears that the absolute increase of the consumption of coal between 1855 and 1859 averaged 0.035 ton per head per annum; that the next six years 1859 to 1865, averaged 0.145 ton per head per annum; while the last four years, 1865 to 1869, only averaged 0.0463 ton per head per annum. From this it would appear that the annual increase has passed through a point of maximum increase, and that it is now diminishing.

Basing their calculation, however, upon an arithmetical instead of a geometrical increase in the rate of consumption, and simply adding a constant quantity equal to the average annual increase of the last 14 years, taken at 3,000,000 tons, the Commissioners arrive at the following result, namely, that at the end of 100 years the consumption would be 415,000,000 tons per annum, and that the now estimated quantity of coal available for use would represent a consumption of 276 years. Taking, however, another view of the case, and supposing that from this time the population of the whole country and the consumption of coal per head of that population will remain constant, or merely oscillate without advancing, our available coal would represent a consumption of upwards of 1,273 years, at the rate of 115,000,000 per annum.

These two calculations, as to the probable duration of our coal resources, given by the Coal Commission in their Report, may probably be taken to represent two extreme cases, between which the actual truth may probably be found. Whilst, then, we may confidently anticipate the continued existence of coal for some 300 years at least, it by no means follows that its price will remain as at present. With increased depth of workings, and an increased difficulty in raising coal, its price must necessarily rise; and although, therefore, there is no fear that coal will become actually scarce in our time, the same effect will, in a great measure, be secured by its increase in price. The prevention of this evil can, apparently, only be effected by still greater economy in combustion, and the enforcement of a law that no coal, either large or small, shall ever be left in a working beyond what it may be impossible to gain.

STORAGE AND DISTRIBUTION OF WATER IN INDIA.

From "The Mechanics' Magazine."

The following is an abtráct of a paper read before the Institution of Civil Engineers in London, by Mr. Geo. Gordon, C. E.:

The author gave an account of the ancient native and the modern systems, under the two heads of Tank and Channel Irrigation. The existing Tank Irrigation was chiefly ancient, and comprised innumerable tanks of all sizes, from what might be termed lakes downwards. These might be divided into three classes: 1. Those formed by the closing of the passage of a considerable river through a narrow gorge, in a range of hills, by means of a high dam or "bund." 2. Those formed in the plains, by embankments carried across the drainage of the country, and impounding the water of one or more streams; these tanks being often of great superficial area but shallow. 3. Tanks which might be considered intermediate between the other two, having in general a greater length of dam than the first, and a greater depth of water than the second. Few examples of the first kind remained entire. A description was given of the ruined Mudduk Masoor Tank, one of this class situated on the borders of Dharwar and Mysore, of which the following were the principal dimensions: Length of the main bund on the crest, 550 yards.; present height from 90 ft. to 108 ft.; width at the base, from

945 ft. to 1,100 ft.; area of the lake at 90 ft. depth, 40 square miles; contents about 1,400 million cubic yards of water. The area of the drainage basin, which was on the inner slopes of the Western Ghats, was 500 square miles. The author was engaged on a proposed restoration of this tank; but it was found that the present average rainfall would not suffice to fill much more than one-half of its ancient basin, and it was suggested that the depth should be reduced from 90 to 70 ft. This diminution in the supply was supposed to be attributable partly to the diminished rainfall and partly to the construction of small tanks on some of the feeders, at a date subsequent to the completion of the Great Tank, which was assigned, by tradition, to the 14th or 15th century. The main bund was supplemented by two smaller ones, placed on saddles at some distance from it, in the range of hills; and it was by the breaching of one of these that the tank was ruined, as the principal embankment remained entire. There were no traces of a waste weir or by-wash of any kind. The second and third classes of tanks were then described, some ancient ones of great dimensions being noticed, such as the ruined Poonairy Tank, in the Trichinopoly district, of which the embankment was 30 miles in length, and the Veeranum Tank, still in action, with a bund 12 miles long. Under the head of Channel Irrigation, it was stated that only rivers of the larger class, which had a continuous flow for several months, were available for extensive irrigation projects. The smaller rivers were merely torrents, which quickly carried off heavy falls of rain, and then became dry again. The water, however, was in many cases intercepted by chains of tanks, of the second or third class, built across these torrents.

The deltas of large rivers, being the most easily irrigated lands, had been so treated for ages, and the works had been much extended and improved under the British Government, by the construction, by their able engineers, of permanent weirs of great lengths, at the heads of the deltas, such weirs being built on the sandy beds of wide rivers subject to heavy floods. This seemed to have been beyond the skill of the ancient native rulers. They, however, built many weirs on the large rivers in the middle part of their courses; the situations being skilfully chosen, but the construction was rude and imperfect. They were generally built on a reef of rocks, with loose rubble, faced with large blocks of granite laid dry, and sometimes fastened with iron clamps. The modern weirs in similar situations were of masonry, with a vertical or slightly battering face on the down-stream side, and with heavy copings. In rivers having sandy beds, it was usual to build the body of the weir on a foundation of brick wells, sunk to the low water level, and filled with concrete. On the lower side there was an apron, having a slope of 1 in 12 from the crest, with a toe wall; and if the slope was long, intermediate walls were also built on wells, and below all there was a broad layer of rough rubble of large dimensions.

The ancient irrigation channels were generally defective in design, being too small, and having much too great a fall. In consequence of these channels being so near the river, they irrigated only a narrow strip of land, and the current being too great, excessive annual repairs were required. This system necessitated numerous offtakes from the river, involving the expense of many weirs, and a great aggregate length of unproductive channel from the offtake to the point where the channel reached such a level as to command the surface of the country. On the other hand, a canal of large dimensions, taken off from one head, having a slower current and less fall, would soon so gain on the level of the river, that it would reach districts remote from it, and consequently more in need of artificial supplies of water; and it would also command a much larger extent of country than it could supply entirely with water. This was an advantage, because it would be many years before a district could be completely changed from dry to wet cultivation, as it would require to have its population trebled. It also afforded means of assisting dry crops in years of drought, and thus preventing famine. In many districts complete failure of the crops now grown occurred every few years, and a good crop was a rare occurrence. There should, therefore, be facilities for completely irrigating detached areas at considerable intervals, and of giving occasional irrigation to dry crops.

Distribution was effected from the second class of tanks directly by means of sluices in the bund. From the third, and more especially from the first class, it was commonly effected indirectly; thus, the natural channels of the river or rivers, which had been dammed to form the tank, were used to carry part of the water for irrigation, weirs being built across them at suitable places and artificial channels taken off from above them. By these means the surplus of the water, which was generally wastefully used by the ryots, was saved, being collected by drainage into the stream, and redistributed at the next weir. Distribution was most economically effected from a canal, when the latter ran along a ridge; but as this could rarely be accomplished in the case of a canal taken off from a main drainage, it was next best effected by leading the main distribution channels down the ridges crossed by the canal. Distribution could be carried out in the Ceded Districts for 5s. per acre, including sluices in the main canal, and all necessary road and water crossings, but excluding the cost of terracing the land to prepare it for wet cultivation, this being done by the occupier. The nature of the ground was such, that, in the districts to which the Paper referred, the drainage was effected naturally, no works being required for that purpose beyond small open trenches in the rice fields.

The value of water to the cultivator was shown, first, by contrasting the yield of dry crops with that of rice and sugar cane, from actual experiment. From these it appeared that the net profit per acre on dry crops was 8s. 2½d.; on rice, £4 16s. 10½d., and on sugar cane, £18 6s. 6d. In the two last cases, a very low rate for the water was assumed, viz.: 12s. per acre for each crop of rice, and 24s. per acre for each crop of sugar cane, as provisionally paid by Government. A comparison between dry crops and rice, and dry crops occasionally flooded, was then made, based on the average price of grain extending over five years and deducting one-fourth from the gross value of the crop in the case of dry crops, and one-sixth in the case of wet crops, to cover loss in bad years. Without deducting the water-rate, the difference in the net value of the crops was as follows: between dry crops and rice, taking the most unfavorable comparison, 25s. 7d.; between dry crops and the same occasionally irrigated, 30s. 8d.; and between two dry crops and sugar cane (which occupied 10 months of the year), £8 2s. 8d. But if water was stored, so as to allow a second crop of rice to be grown, the advantages were nearly doubled. The author then showed that, provided a water-rate proportioned to the value of the water were fixed, irrigation would benefit the cultivator to the extent of 8s. 6d., or 50 per cent., and yield a gross return on the outlay of 14s. 9d. per acre; and if water were stored for a second crop, the gain to the cultivator would be 19s. 9d., or more than 100 per cent., and the return to the agency supplying the water 37s. 3d. per acre, the cultivator not having to expend any capital in improvements. Of the 37s. 3d. per acre profit 22s. 6d. was about the sum due to the storage of water, supposing such storage works to be added to distribution works already constructed. It was shown that the cost of large works of irrigation might be safely reckoned at £7 per acre on an average, or £8 15s. if 5 per cent. on one-half the capital for 10 years during construction were added. If the profits made by the application of the water were divided, in the proportion of one-third to the cultivator and two-thirds to the agency supplying the water, works of channel irrigation would benefit the cultivator, as above stated, to the extent of 50 per cent., and would yield a net return of 7.4 per cent. on the capital expended.

With respect to the cost of tanks, the author gave some figures to show that the construction of flat country tanks of the second class, or even of the third class, would offer a very doubtful return, although in some cases it might pay the cultivators to construct them. Great profits had been made by Government in several cases, by restoring or repairing tanks, and also channels which had become ruined; such net profits amounting to from 10 to 45 per cent., and in one instance, which was cited, to 250 per cent. The construction of large storage reservoirs would, the author considered, return a very large percentage on the outlay. Although none of large capacity had yet been constructed, it appeared probable that, in the most favorable locality, 7,000 cubic yards of water could be stored for £1, and in others 4,250 cubic yards, while the restoration (in part) of the ancient tank of Mudduk Masoor, already mentioned, would yield 9,600 cubic yards per £1.

The loss by evaporation in the reservoirs of 70 ft. and upwards in depth would vary with their depth, and the time in which they were emptied. It was found, by observations of the evaporation in the locality of 3 proposed reservoirs, to vary from 5 per cent. to 7½ per cent. of their contents. A further loss from the same source would occur in the passage of the water to the country to be irrigated, varying of course with the distance, etc. For the purposes of calculation, the correction for evaporation was assumed at 12 per cent., and the quantity of water required for the cultivation of an acre of rice at 5,000 cubic yards. At the most unfavorable rate of storage (4,250 cubic yards £1, and adding, as in the case of the channel works, 25 per cent. for interest during construction) 3,400 cubic yards per £1, the prime cost after all deductions would be £1 9s. 5d. per acre, for giving a second crop of rice, or a crop of sugar cane;—while the cost at the rate at which the restoration of the Mudduk tank was estimated would be 14s. 10d. per acre. Reference to a table in the paper showed that an outlay of £1 9s. 5d. would yield a net return of about £1 1s. This allowed a large margin for the construction of reservoirs in still less favorable situations than the least favorable one which the author had examined. This statement supposed the reservoir to be constructed in addition to a system of distribution works already existing. The author had excluded the subject of navigation from his paper, as no general rule could be laid down, as to whether it could or could not be economically combined with irrigation. With regard to the large and very remunerative works in the Kistna, Godavery, and Tanjore deltas, it was mentioned that the works in the latter yielded, after deducting repairs and 5 per cent. on the capital, 23½ per cent. direct profit, and those on the Godavery from 50 to 60 per cent. These examples were only incidentally alluded to, because all the deltas, were so occupied as to offer no opportunity for new undertakings on a large scale, while in other districts such enterprises would necessarily be more expensive.

The author submitted the following conclusions: 1st. That irrigation would benefit the cultivator to such an extent as to enable him to pay a water-rate equal to two-thirds of the increased value of his crop, and still leave his own profits from 50 per cent. to 400 per cent. in excess of those derived from dry cultivation. 2d. That the most profitable application of capital would be found in the construction of storage reservoirs as an addition to distribution works already in existence, and that these would yield a net return of 46 per cent., after paying one-third of the gross revenue to the existing works, and increasing the revenue of such works by 4¼ per cent. 3d. That the arbitrary water-rate of 12s. per acre was, on the data assumed by Government, insufficient to yield a fair return directly on the average of new irrigation works, unless these included the storage of water for a second crop. 4th. That the profitable employment of capital in irrigation depended chiefly on the recognition of the principle that the water-rate should be fixed with reference to the value of the crop produced by and the cost of the works in each case, and that otherwise many very beneficial projects would remain unexecuted.

MARINE ENGINE CYLINDERS IN THE NAVY.

From "The Engineer."

In our last impression we called the attention of our readers to an interesting paper on compound engines in the navy by Mr. Pratten, and published in the Annual of the Royal School of Naval Architecture and Marine Engineering. We now propose to deal with a paper in the same publication, "On the Marine Cylinder, as fitted in the Navy," to which we have already alluded. We stated, it will be remembered, that the author of this paper —Mr. Seaton—drew a very deplorable picture of the present position of marine engineering as regards our navy; and we cannot better introduce our subject than by explaining that Mr. Seaton's paper goes from beginning to end to show that nothing can be more unreliable than the cylinders of our largest men-of-war. He begins, curiously enough, by stating that "Perhaps the most important improvements made during the last 10 years in the marine engine have been made in the design and construction of the cylinder," but a few lines further on he says, that "No one will deny the need of still further improvement—no one at any rate acquainted with the lengthy catalogue of cylinders broken year by year in her Majesty's navy." Now, any one who is in the habit of reading the naval and military intelligence of the "Times," must have found mention made occasionally of cracked cylinders or condensers, but it is equally certain that every engineer of experience will attach little importance to statements of the kind made in a way to convey the impression that the cracking of a cylinder is a very unusual event. Indeed engineers whose experience has been confined altogether to the mercantile marine, are not in the position to realize the astonishing frequency of the occurrence in the navy. Judging from their own practice they will be certain to attribute the cracking of a cylinder to priming, and possibly to negligence on the part of the engineers in charge. Mr. Seaton, however, puts the matter in a very different light. He shows that cracked cylinders are the rule rather than the exception. "Experience," he tells us, "teaches that mere thickness of metal will not suffice, for Messrs. Maudsley's heavy castings are no more infallible than Messrs. Penn's light ones," and he cites numerous instances in proof of this proposition. Thus he tells us of one new iron-clad of 800-horse power which arrived at the port where she was to be fitted out immediately after launching, with both cylinders cracked. The Constance cracked one of her cylinders on one of the very few voyages she ever made, namely, the competitive run to Madeira. The radial ribs in the reservoir of the engines of the Tenedos—decribed in our last impression—are cracked. The engines of the Black Prince suffered much during her first commission, the forward cylinder being cracked extensively in a line parallel to the axis. The Lord Clyde had to come home from the Mediterranean with both cylinders cracked. The cylinders were re-bored and fitted with bushes at great expense. These bushes cracked on the trial trip, and the cylinders had to be taken out and replaced by others of somewhat different design. The unfortunate Magæra, it will be remembered, had both cylinders cracked. One of the cylinders of the Hercules has been cracked within the last few weeks. "More instances might be given," Mr. Seaton adds, "all tending to show that cast iron should not be used alone for the immense cylinders required for our steamers." Even when the cylinders do not break, they score. As an instance we may cite the Agincourt, whose cylinders were deeply scored by merely steaming from Liverpool to Devonport, and making a few trial trips.

Mr. Seaton makes one or two suggestions as to the arrangements to be adopted in future for getting over the difficulty, but they are not very satisfactory. One is that the cylinders should not be bolted down too rigidly, so that they might not only be free to expand and contract, but also be relieved from the chance of strain due to the working of the ship. He adds that the usual plan is to make a firm connection to the front bearers, oval bolt holes at the other end of the cylinder allowing for expansion ; but he admits, almost, in the same breath, that fracture of the cylinders takes place in spite of this arrangement. His great remedy, however, is the use of some material other than cast iron. Unfortunately he has not settled what this material is to be. He is not enterprising enough to venture to think that we can make cylinders 120 in. or so in diameter, of steel ; but he ventures to suggest a more extensive use of wrought iron in framings and jackets. We reproduce a striking paragraph which puts his views on the subject very clearly: —"We cannot go on much longer without making some decided alteration in construction, for even cracked cylinders become monotonous after a time, and it would be a disgrace to the profession to wait until a coroner's jury had taken the matter in hand. It does not seem such a difficult task to place a cast iron, or even steel, bush in a wrought iron shell, and still, by a judicious arrangement, maintain all the requisite stiffness. Until something of the kind is done we may expect to hear more of cracked cylinders than will be pleasant, and the delay may be the means of stopping more than one improvement still required to make the engine perfect."

Mr. Seaton's paper is a startling commentary on the conditions and prospects of marine engineering, and it is worth while to consider to what cause the repeated failure of cylinders in the navy is due. It will not do to attribute it wholly, or, as regards our latest vessels even in part, to the working of the hull in a heavy sea. Our iron-clads are much too stiff, thanks to their double bottom, to work appreciably. The true source of the mischief is to be found in the fact that the cylinders are too large and too complex regarded as castings, and the horizontal type of engine is apparently unsuitable for use under the required conditions. We hear little or nothing of cracked cylinders in the mercantile marine, firstly, because the cylinders, as a rule, are much smaller than the monstrous structures in the navy; and, secondly, because they are by preference always arranged vertically, this last statement holding perculiarly true of modern compound engines. We shall be called heretics if we say a word in condemnation of the horizontal type of engine, but we cannot help that. The horizontal engine is excellent in its way, but it is attended with serious disadvantages when made of great dimensions. There is not a portion of the cylinder in equilibrium, so to speak. It is exposed to an endless variety of complex strains, due to its own weight, that of the valve chest and valve hung on to the side, and those of the various attachments, such as steam pipes and exhaust pipes; besides, it is continually traversed by a piston weighing several tons, always tending to settle down to the lowest point, and beyond question exercising a certain tendency to alter the shape of the comparatively thin and weak cylinder to suit itself. It is simply impossible, again, to make large cylinders covers so stiff that they will not spring. Thus the load brought to bear on the lid of a cylinder 100 in. in diameter, and working steam of 40 lbs. total pressure, will not be much short of 80 tons. The lid in springing tends to draw the cylinder sides inwards, and sets up, besides, very awkward strains through the flanges. When a cylinder is disposed vertically much of the difficulty is got over; the weight of the piston, in the first place, in no way affects the cylinder; again, there is no tendency to distortion due to position.

The pull of the valve chest is taken in the line of the axis of the cylinder, instead of at right angles to the piston-rod. In a word, a great number of cross strains are got rid of, and the metal is, so to speak, left more at its ease; while last, and not least, as the cylinder is secured only at the lower end, it is free to expand and contract as it thinks proper, and it is almost entirely spared from any strain due to the working of the ship. It is no wonder, therefore, that we hear little or nothing of cracked cylinders in the mercantile marine. In the navy, however, it is imposible to use vertical engines without introducing evils greater than those which we wish to avoid. In what direction, then, shall we look for immunity from cracked cylinders? We think the answer is sufficiently obvious. It is to be found, first, in reducing the size of the cylinders within reasonable limits and augmenting their number. Thus, two pistons, 70¾in. diameter, have the same area as one of 100 in. in diameter. Of course, by increasing the number of cylinders from 2 to 3 or 4, we introduce more complication, and slightly increase the weight and the space occupied by the engines. On the other hand, however, we could dispense with one or two objectionable features—such as the back piston-rod absolutely essential to prevent scoring in large engines, and we might considerably simplify the framing, and adopt superior methods of fixing the cylinders. The 3-cylinder type, introduced by Messrs. Maudsley and Field, gave sufficiently good results in many cases to render it probable that it could be used more generally with advantage. We frankly confess that we see no way, in the present condition of the arts of construction, of avoiding the fracture of cylinders in engines of enormous power, other than arranging them vertically, or increasing their number and reducing their size within reasonable limits. We cannot adopt the first plan; the second is open to certain objections; but anything is better than the incessant breaking down of machinery on the permanence of which in time of war the whole safety of the nation might hang. The question becomes daily more serious, inasmuch as many of our most powerful iron-clads are to be without masts and sails. What, for example, would become of the Glatton if she split her cylinders, even in going from one port to another? It may yet happen that reliable steel castings, weighing 25 or 30 tons, can be made; but until then there is little to be hoped for from steel as a material for marine engine cylinders.

FORMULA DEDUCED FROM THE PRISMOIDAL FORMULA, APPLICABLE TO THE LARGE CLASS OF PRISMOIDS MET WITH IN THE CONSTRUCTION OF RAILWAYS.

By D. J. WHITTEMORE, C. E.

Many of the cross-sections, taken for the purpose of measuring the volume of grading required in the formation of railway excavations and embankments, are what may be called three height sections, said heights being the two slope stake heights and the centre line height of the natural surface of the ground above or below the roadway, which roadway is of uniform width, and the slopes on either side have equal angles of inclination. On many railways, 95 per cent., at least, of the cross-sections taken for the above purpose, are of this kind.

Any formula that expresses accurately the volume contained between two such parallel sections, the heights of which are all plus or all minus, that is an improvement over any of the methods now in general use, will be thankfully received by the practical civil engineer.

Applicable to such cross-sections, I have devised the following formula:

NOTATION.

Let the cross section at the end of the prismoid be known as the 1st section, and the one at the other end as the 2d section; then

Let $S = \frac{1}{2}$ sum of slope stake heights of 1st section.
" $S' = \frac{1}{2}$ sum of slope stake heights of 2d section.
" C = centre height of 1st section,
" C' = centre height of 2d section.
" W = width of roadway.
" L = length of prismoid.
" V = volume of prismoid.
" r = three times the vertical measure divided by twice the horizontal measure of slope.

Algebraically, express the prismoidal formula, using the above notation, then there will result on reduction the following

FORMULA.

$$\left\{(2S + S')C + (2S' + S)C' + (S + S' + C + C')\,r\,W\right\}\frac{L}{4r} = V$$

It is readily seen, that the numerical value of r for any slope, the angle of which is known, may be determined by dividing three times the sine by twice the co-sine of the angle.

In the following formulæ r is given its numerical value, for each of the slope inclinations indicated.

FORMULÆ.

Ratio of slope ¼ to 1
$$\left\{(2S + S')C + (2S' + S)C' + (S + S' + C + C')\,6\,W\right\}\frac{L}{24} = V.$$

Ratio of Slope ½ to 1
$$\left\{(2S + S')C + (2S' + S)C' + (S + S' + C + C')\,3\,W\right\}\frac{L}{12} = V.$$

Ratio of slope ¾ to 1
$$\left\{(2S + S')C + (2S' + S)C' + (S + S' + C + C')\,2\,W\right\}\frac{L}{8} = V.$$

Ratio of slope 1 to 1
$$\left\{(2S + S')C + (2S' + S)C' + (S + S' + C + C')\,1\tfrac{1}{2}\,W\right\}\frac{L}{6} = V.$$

Ratio of slope 1½ to 1
$$\left\{(2S + S')C + (2S' + S)C' + (S + S' + C + C')W\right\}\frac{L}{4} = V.$$

Ratio of slope 2 to 1
$$\left\{(2S + S')C + (2S' + S)C' + (S + S' + C + C')\,\tfrac{3}{4}\,W\right\}\frac{L}{3} = V.$$

In applying the above formulæ it would be convenient to have a column in cross-section book for the sum of the slope stake heights of each section, which sum would represent, in the formula, the value of 2 S or 2 S′, as may be required.

This method of computation requires 4 additions, 4 multiplications, and 1 division, or 9 processes in all. Ordinarily 2, and in many instances 3 or 4 of these processes can be performed mentally.

When the ground line of end-section is level, either of the following formulæ may be advantageously used :

$$\left\{(C + C')C' + C^2 + (C + C')rW\right\}\frac{L}{2r} = V.$$

$$\left\{C^2 + (C + C')(C' + rW)\right\}\frac{L}{2r} = V.$$

When $S = C$ and S' and $C' = 0$ the following formula is correct :

$$(C^2 + CrW)\frac{L}{2r} = V.$$

When S and C are unequal, and S' and C' each equal $= 0$, the following formula can be used:

$$\left\{2SC + (S + C)rW\right\}\frac{L}{4r} = V.$$

The formula first written is correct for all of these conditions, the latter being simply deductions from it.

THE NAVY OF THE FUTURE.

From "The Mechanics' Magazine."

A semi-official communication to the "Times" prepares the way for an application to Parliament for funds to build a ship of war which possesses the merit of novelty of construction. The new vessel is to carry the armorplating on the bottom, leaving the topsides unprotected, and, to compensate for this disposition of weight, the coals and stores and cables will be above the water-line. She is to be armed with submarine rocket-tubes for the projection of rockets possessing the inherent property of preserving a given depth of immersion, and which will explode a charge of gunpowder or other explosive, on coming into contact with any solid substance, such as a ship, and hence called a "fish" torpedo. Bold as is this newest essay after novelty, we confess that before launching into the enormous expenditure attendant on the building of a bottom-armored ship, we think a few tentative experiments might well precede the outlay, in order to ascertain the properties both of the bottom-armor and of the submarine rocket or fish-torpedo.

It does not appear very clear why a torpedo vessel, of all others, should carry bottom armor unless especial danger be apprehended from her own weapon. We should have supposed that a torpedo vessel had more to fear from the guns of the ship attacked, than from torpedoes other than her own. A torpedo vessel with light upper works approaching an iron-clad would naturally be exposed to heavy artillery fire, against which bottom-armor would be no protection. Indeed, in such a duel, the positions of the armor in the two ships had much better be reversed—the gun-ship be armored below, the torpedo one on top. But there is not a single experiment extant to show what thickness of bottom-armor will resist a given explosive charge. We know that, 150 ℔s. of gunpowder, placed 19½ ft. from the bilge of a wooden ship-of-war, drove her bottom through the upper-deck, making a hole large enough to drive a coach and six through. We know also that a charge exploded against a strong submerged target with an iron tank backing, smashed in the air-tight backing, even when the face of the target was uninjured. But what would be the effect of exploding 150 ℔s. of gun-cotton or dynamite in contact with the armored bottom of a ship has never been ascertained, as it might easily be by fastening a section of a well-constructed vessel against the bottom of an old ship. We do not know that the bottom-armor would save the ship, even from her own torpedo, which appears to be the chief object.

Then, as to the fish torpedo, no experience has been obtained with it, except a close experiment made at Sheerness, witnessed by very few officers, and by none who had made torpedoes their special study. The fact that its construction and use is a secret, shows that no useful experience has been obtained with it. It is generally known that it has powers of maintaining a given depth of immersion, that it proceeds very slowly through the water, that all control over it is lost the moment it is liberated from the operating vessel, and that it explodes on making contact with any vessel, friend or foe. Now, it follows from this, that a self-acting dangerous mine being set adrift in the midst of a fleet, and missing its mark, occupies an unknown position a few feet beneath the surface, and may easily come into destructive contact with friendly vessels, if not with the operating one herself whilst performing the gyrations and manœuvres incidental to a naval action. Such a weapon must be a fruitful source of danger to the fleet in which it is carried, unless some means be provided by which its ignition will be effected or prevented on the lapse of the estimated time for reaching the ship aimed at. Even then, great danger may arise from friendly vessels unknowingly intercepting the path of the fish torpedo. Surely, experiments to discover the means of safety might well be conducted with some old vessel, before building an expensive sub-armored ship, to carry a weapon which may subsequently be proved to be more dangerous to its friends than its foes. Meanwhile, we have safe naval torpedoes, requiring but a few thousand ℔s. and a few intelligent experiments for their full development. If some of the £15,000 given for the paper describing the fish-torpedo, had been devoted to careful experimental investigations as to the properties of the outrigger and of the towing torpedoes, we should probably long ago have possessed safe naval torpedoes which could be employed by any steamship afloat, however built. As it is, we are rushing into a heavy expenditure in building a novel vessel, without a single tentative experiment to justify the supposition that bottom-armor will be effective against torpedoes, or that a fish-torpedo can be safely and usefully employed whilst no protection is to be afforded to the discharging vessel against guns, which are the only weapons she need fear, except her own.

ON THE STRENGTH OF CEMENT.*

By Mr. G. F. CHANTRELL.

From "The Engineer."

In undertaking to bring this subject before the Society it was understood with the secretary that it was (considering the short time given me to prepare this paper) to be only a short sketch, and more for the purpose of initiating a valuable discussion on a very important subject. It is to be regretted that there yet exists a great deal of ignorance in this part of the country of the value of Portland over Roman cement, the latter being still, in this town, the most commonly used. The great distinction between these two cements is that the former is an artificial product and the latter a natural one, being simply *calcined* limestone, ground to fine powder, containing in general a variable quantity of about 60 per cent. of carbonate of lime or magnesia, with from 30 to 40 per cent. of clay, with small portions of oxides of iron and magnesia. The clay is highly ferruginous in character, which accounts for the quick setting of this class of cements. The Roman cements used in this market are mostly from the neighborhood of Glasgow, from Holywell, South Staffordshire, and in a minor degree from London and neighborhood, such as the Harwich, Southend, Isle of Wight, Medina, Atkinson's, etc., and the various imitations made from lias lime.

The earliest Roman cement was brought out and patented by Mr. Parker, near the close of the last century. A very good example of this cement may be seen in perfect preservation on the west front of Lichfield Cathedral, which is coated entirely with it. This cement was made by the firm of Wyatt & Parker, and the work was done under the directions of Mr. Wyatt, the architect, an ancestor of Mr. T. H. Wyatt, President of the Royal Institute of British Architects, and Architect of the Liverpool New Exchange. The natural cements cannot be relied on for regularity in strength, but the property of quick setting has great attractions to the plasterer for running cornices. Portland cement, if good, is much slower. In London, the use of Roman cement is on the decline, owing to the superiority in the strength and decided economy of

* Read before the Liverpool Polytechnic Society.

Portland, and partly that the stone of which the original "Parker's" cement was made (that from the Island of Sheppy) is not to be had in quantity; formerly it was to be got easily, being a shingle which was well water-worn; only the hard kernel of the stone was left, the softer and more worthless being washed away. As this stone became scarce the cement makers were driven to use the Harwich stone, which is quarried out of the rocky shore; the surface stone being to a considerable extent perforated by that remarkable boring bi-valve, the "Pholas Dactylus," or, as our friends the Germans call it, the "stein bohrer," the stone borer. Occasionally this stone may be seen landing in the Liverpool Docks, being used as a ballast for the grain vessels coming from Harwich, and is always secured by the local cement makers to mix with the Holywell stone. It is easily recognized by its perforated appearance. Many years ago the Scotch cement stone was imported here for the same purpose, the combination making a very superior cement, but the "cannie Scot" found it more profitable to manufacture it than to ship the raw stone.

Portland cement, of which I shall have more to say, is an artificial preparation, consisting of varying proportions, according to quality, of chalk and clay intimately combined. The chemical ingredients of the best selected materials are:

Chalk: lime, 56.5; carbonic acid, 43.0; water, 0.5.

Clay: silica, 68,45; alumina, 11.64; carb. lime, 0.75; oxide of iron, 14.80; soda and kali, 4.0.

The usual mode of preparation is to reduce these, by different mechanical arrangements, with the aid of water, and the quality of the cement depends on the care with which this is done. The mixture is run into reservoirs to settle, the water carefully decanted off, and as soon as it is sufficiently solidified it is in this plastic state made into small balls or bricks, and dried on a hot floor, the space below being coke ovens. These bricks are then placed in suitable kilns, where they are highly burnt with coke to what is technically called clinkers. These are then passed on to the grinding mills.

The intimate combination of the raw material is one of slow and tedious operation; attempts have been made to accomplish this by a dry process, but the success is uncertain and variable. It is sometimes called the German process, and is not not confined to chalk lines merely. A so-called Portland cement is made in the lias lime districts. I am glad to say that this market is now pretty bare of these, what I may term, bastard Portland cements. The manufacturers have had no scruples in grinding up heavy materials purposely to add to the weight and not to the cementitious qualities, so as to bring it up to the weight of genuine Portland. Natural cements, such as Roman and Bath, weigh from 70 lbs. to 80 lbs. per bushel, and London Portland 100 lbs. to 125 lbs. There are manufacturers in these districts who have turned out Portland cements quite up to the London in strength, but I do not find that they are cheaper.

We have had works established in this neighborhood, but they do not seem to have succeeded financially.

The Thames and Medway manufacturers have great advantages in having their raw material close at hand, and having cheap water carriage.

It is to the foreigners we are indebted in the first instance for the very great improvement made in the quality of Portland cement, and this is due to the superior technical education of foreign engineers. They take infinite pains in testing all the cements used by them on public works, a certain standard of strength being specified, and rigidly enforced. The manufacturers who cultivated this export trade found themselves compelled to pay increased attention and care in the manufacture, and the result has been an enormous increase of the trade.

The extensive character of the main drainage works, carried out for the Metropolitan Board of Works, under the direction of Mr. Bazalgette (the well-known engineer), led to the adoption of a regular and careful system of testing of all the cements used on these works, which were commenced some twelve years ago.

I have the advantage of the tables of results, carefully made by Mr. John Grant, M. Inst. C. E. (who was associated with Mr. Bazalgette), and published by him in the 25th vol. of the "Transactions of the Institution of Engineers," and also in the more recent ones in the 32d vol., session 1870-71.

The following is the first specification as to the quality of cements used on these works:—"The whole of the cement to be Portland cement of the very best quality, ground extremely fine, weighing not less than 110 lbs. to the striked bushel, and capable of maintaining a breaking weight of 400 lbs. seven days after being made in an iron mould of No. 1 form, and immersed six of these days in water."

The last specification used is as follows:—"The whole of the cement shall be Portland cement of the very best quality, ground extremely fine, weighing not less than 112 lbs. to the striked bushel, and capable of maintaining a breaking weight of 250 lbs. per sq. in., seven days after being made in a brass mould, and immersed in water during the interval of seven days. The contractor shall at all times keep in store upon the works a supply of cement equal to at least fourteen days' requirements, and with each delivery of cement shall send to the clerk of works a memorandum of the number of bushels sent in and the name of the manufacturer."

The moulds used were of the form shown in drawing as No. 1, being $1\frac{1}{2}$ in. $\times$ $1\frac{1}{2}$ in. in the centre, or breaking point, and $= 2\frac{1}{4}$ sq. in. A lever testing machine on the principle of the steel yard, and similar to the one I have brought here to-night, was used. I believe this machine is the only one in Liverpool, and I shall be glad to allow any one to use it, as I firmly believe the more common testing becomes, the better and more regular this cement will be made. The sale will increase the more its good qualities are known and appreciated.

I am glad to see that manufacturers are making the result of tests a marked feature in their circulars; but unless buyers have testing machines they will still be in the dark, as gauging small pats of cements and testing with the point of a knife is very fallacious.

At the Southern High Level Sewer (1859) every precaution was taken by Mr. Grant (the resident engineer) to have the apparatus fixed in testing houses on the works; access to these premises could only be obtained by the proper officers; ordinary workmen were soon trained to the work of gauging and testing. In six years more than 70,000 tons of Portland cement were used, and 15,000 tests made. It is a singular fact that the manufacturers strongly urged that only a standard of 300 lb., instead of 400 lbs., would in practice be found attainable; but luckily for the trade the higher standard was maintained, and before long without difficulty. At first a few parcels were rejected, but the same manufacturers persevered, and soon turned out a higher quality, and the tests show that in practice the standards fixed from time to time were, as a rule, far exceeded.

To the French and German engineers, in the first instance, are we indebted for initiating the process of tensile testing, which was followed by the engineers of the Metropolitan Board; and one of the most valuable contributions to the engineering world is the set of tables published by Mr. Grant.

The very marked increase in the manufacture of this cement is due to the increased confidence of engineers and contractors, who were aware of the precautionary measures adopted, and the very satisfactory increase in the standard of strength made during the progress of these important works.

The adoption of great care in the testing of cement is of little avail, unless the same rigid care is observed in selecting the sand to be used, and also in the proper amount of water.

Great mistakes are made in this neighborhood in using too fine sand; it is very common to hear of North Shore sand being specified to be used with cement. Cement is very frequently condemned when it is perfectly good, and this may be solely attributed to using improper sand. Not many months ago I had fault found with some Portland cement, which the architect prefaced his appreciation of by condemning before any of it was even gauged, and then he subsequently allowed the contractor to use the fine drift sand of Formby with it, showing his utter ignorance. A sample of the gauged stuff was brought to me, when I immediately saw what was the matter—it was quite soft and crumbly; I threw a portion into water, and it soon hardened, as shown in the sample submitted; the setting in water showed the cement was good, but it had been impoverished by the immense surface it had to cover.

The setting of cement is the chemical

action of crystallization. The cement must cover the whole surface of the contained sand ; if the sand be too fine it has no chance of surrounding each particle ; the coarser the sand the less surface there is to cover, and the cleaner it is, the more perfect the crystallization will be. If these facts were always borne steadily in mind we should hear less of failures, and the merchant and manufacturer would be spared many undeserved condemnations.

It is much to be deplored that it is so commonly intrusted to unskilled laborers to mix cement. Very frequently cement that has set is wetted up again, and for this, if any harm result, the quality of the cement is called in question. The marked difference in this respect to be seen on the Continent is due, I suppose, to technical education in contrast with the too general rule of thumb in this country. Proper mixing boards are still very rare ; but on the Continent they are used as a rule, and the utmost care is taken in incorporating the sand and gravel with the cement before adding the water, as also in having the sand and gravel well washed.

To show the carelessness in this respect, a cement dealer in a neighboring town plastered his office inside with the best Portland cement as a sample. Shortly afterwards, treacley stains were seen in patches over the wall. On investigation it was found that small bits of coal had got into the sand ; these stains were due to the coal. I have known several instances in which Minton's buff tiling has been ruined by sand in which peaty lumps have occurred; the chemical action of the cement on these has resulted in black stains in the tiles. A more recent instance—the proprietor for whom the work was done stipulated to find his own sand, and the tiler, being a young hand, laid the tiles, and peaty stains were the result.

In a discussion on Mr. Grant's first paper, Mr G. F. White, in calling attention to the weight of Portland cement, and the tendency of manufacturers, in making heavy cements, to combine an increased proportion of lime to enable them to push the calcination to a higher degree, to increase the density, said that it was at a risk of an imperfect amalgamation of the lime and clay, causing the fatal disintegration which many engineers have had to complain of. No doubt, for general builders' purposes, a Portland cement of a lighter gravity, say from 104 to 108 lbs. per bushel, would suit better, on account of its quick setting ; but for engineering works of extensive character, and where time can be given for setting, the higher specific gravity must be both cheaper and more reliable. The very fact that the specified standard test was raised from 400 lbs. to 787.5 in something like 12 years, and that Mr. Grant's experience during the progress of these important works, as evidenced in the tables published by him, shows that, as a rule, the manufacturers were exceeding the specified strength considerably, and tells its own tale.

I will read you a few of the results I have gathered from Mr. Grant's valuable tables, and I trust, in the discussion that will follow, we may be able to add some of our local experience to the list. I hope, on some future occasion, to give you a more carefully prepared paper on this most important subject—this being a mere sketch. I must also leave another branch of this subject, that of "concrete construction."

When the nature and value of Portland cement is more and better understood we shall find the remarkable saving that may be made in the construction of cheap dwellings for the working-classes, and the easier adaptation of this material for sanitary appliances, such as ventilation, etc. As far as engineering is concerned, you may remember a fact stated a short time ago, that Mr. Bazalgette has, by the adoption of concrete backing for the granite walls of the Chelsea embankment, effected a saving of £25,000. In the construction of sewers a like economy is found. One sewer at Earl street, Deptford, is 7 ft. 1 in. in diameter, the substance of the upper part of the sewer being only 9 in. and the lower half only 4½ in. to 5 in. Our local engineers would tremble to attempt anything of the sort ; but I trust in a few years to see Portland cement better understood in this town. There is no reason whatever that it should not be as extensively used here as it is in London and on the Continent generally. Several tables extracted from Mr. Grant's well-known work accompanied this paper. We have not thought it necessary to reproduce figures with which most of our readers are more or less familiar.

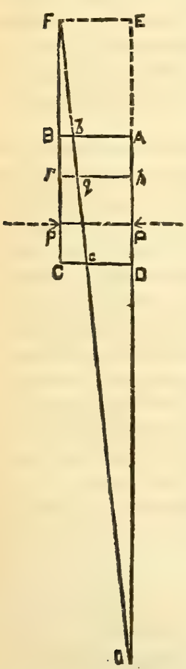
ON THE STRENGTH OF LONG STRUTS.

By WALTER R. BROWNE.

From "The Engineer."

Some weeks ago a correspondence appeared in "The Engineer," on the breaking strain of long struts of timber, in which the wide divergence of the different existing formulæ, both from each other and from the results of actual experiment, was forcibly pointed out. It is the object of the present paper to show that this divergence is inevitable—in fact that the question is one to which no exact formulæ can or ought to be applied.

When short pieces of any material are subjected to compression they yield by crushing or splitting equally in all directions. But with long pieces, such as timber struts, the case is different. They are found to give way by crippling on one side, and tearing on the opposite side, much as if they had been laid horizontally and broken by a vertical load. To this the name of cross-breaking has been given, and very justly; for it is clear, on reflection, that such a fracture can only be due to the fact that the line of resultant pressure does not pass through the centre of the section, as in ordinary crushing it is supposed to do. This deviation (caused by want of straightness, or other defect in the strut) must produce a bending moment on the section, which will break it exactly as in the case of ordinary transverse strain.



The effect may easily be examined theoretically. Let A B C D represent a very thin slice or element of the strut (supposed rectangular) when free from the action of any forces, and then let this element be compressed between two opposite forces, each equal to P, and acting, not through the centre of the section, but along some other line whose distance from the further edge A B $= p$. The effect must clearly be to shorten the element and at the same time to spring it into a curve; but as this curvature will be in our case exceedingly small we may safely neglect it, and with it also the resistance to flexure which depends upon it. The altered form of the element may then be represented by a trapezium such as A b c D, the pressure, and, therefore, the shortening of the fibre being greatest along C D and least along A B. The neutral line, where there is no compression, will be beyond A B, in some such position as E F. Take any fibre $p\,q\,r$ and let A $p = y$. Then, if y be positive A E must be negative. Let A E $= -k$. Let $b\,c$ and A D meet in O, and let A O $=$ R. Let the length A B of the element be s, and the depth A D be d. Then, by Hooke's law, the strain on the fibre $p\ q\ r = \frac{r\,q}{p\,r} \times$ E (where E $=$ modulus of elasticity). But by similar triangles

$$\frac{r\,q}{r\,F} = \frac{E\,F}{E\,O}, \text{ or } \frac{r\,q}{p\,r} = \frac{r\,F}{E\,O} = \frac{y-k}{\rho-k}.$$

Hence the strain on

$$p\,q\,r = \frac{y-k}{\rho-k} \times E.$$

The total strain on A B C D is found by integrating this expression between the limits O and d, and this total strain $=$ P. Hence

$$P = \frac{E}{\rho-k}\left(\frac{d^2}{2} - k\,d\right)$$

Again, the moment about A of the strain on

$$p\,q\,r = y + \frac{y-k}{\rho-k} \times E.$$

Integrating this from O to d, we get the whole moment of the strains on A B C D about A, and this moment $=$ P p. Hence

$$P\,p = \frac{E}{\rho - k}\left(\frac{d^3}{3} - \frac{d^2\,k}{2}\right)$$

From these two equations we obtain

$$\frac{d^2}{2} - k\,d = \frac{1}{p}\left(\frac{d^3}{3} - \frac{d^2\,k}{2}\right)$$

whence

$$k = \frac{3\,p\,d - 2\,d^2}{6\,p - 3\,d}.$$

Now the value of the strain on $p\ q\ r$, as given above, is $\frac{y-k}{\rho-k} \times E$. And it is evident that the point where the strain is greatest is D, for which $y = d$. Hence the strain at D is given by $\frac{d-k}{\rho-k} \times E$. Substituting the value of k found above, and for $\rho - k$, the expression $\frac{E}{P}\left(\frac{d^2}{2} - k\,d\right)$ we have for the greatest strain at any point of the section the expression

$$\frac{(6\,p-2\,d) \times P}{d^2} \times E.$$

If $p = \frac{d}{2}$, this becomes $\frac{P}{d} \times E$, which is the correct expression for the strain when it is rendered uniform by the pressure acting through the middle of the section. If p be greater than this, say

$$p = d\left(\frac{1}{2} + \frac{1}{n}\right)$$

then the expression is

$$\frac{P}{d} \times E \times \left(1 \times \frac{6.}{n}\right)$$

The form of this expression shows how rapidly the greatest strain increases as the line of pressure deviates from the middle of the section. Thus if the deviation be only 1-6th of the diameter, the strain on the outside of the strut is twice as great as it would be if there were no deviation.

It thus appears, that to determine the strength of long struts we must know the point at which the line of resultant pressure cuts any section. How can this possibly be discovered? It may vary to any extent, and mainly from two causes—want of straightness in the strut itself, and bad bedding at the ends, bringing the pressure on one side instead of in the middle.

We might assume that each of these is greater as the strut is longer. In that case p would be proportional to length^2; and greatest strain =

$$\frac{C\,(\text{length})^2 - 2\,d}{d^2} \times P\,E,$$

where C is some constant. Hence the strength would be proportional to

$$\frac{1}{C\left(\frac{\text{length}}{\text{depth}}\right)^2 - \frac{2}{\text{depth}}}.$$

With this we may compare Hodgkinson's formula, which makes the strength proportional to $\left(\frac{\text{depth}}{\text{length}}\right)^2$, or that of Mr. Gordon, which makes strength proportional to

$$\frac{1}{C\left(\frac{\text{length}}{\text{depth}}\right)^2 + 1.}$$

But it is clear that this assumption is far too vague to be trusted. Empirical formulæ are valuable where we are dealing with unknown laws of nature, because we are sure there is a rigid rule if we only knew it. But here variations are due, not to any natural laws, but to defects of material or workmanship, and these no formulæ can cover. The practical outcome seems to be that all rules are misleading, and that each strut must be judged on its own merits. Ascertain first how far it deviates from a straight line. If necessary, bevel off the ends at the concave side, so as to bring the pressure nearer to the other or convex side. Then making allowance for shakes, etc., you must form your own judgment how near the strut may be expected to come to the full strength of the material to resist crushing in the ordinary way, and this being a a known quantity the strength of the strut is given as nearly as seems likely to be attained in practice.

THE MANUFACTURE OF IRON AND STEEL RAILS.*

In order to get an idea as to the strength of steel rails, it will be well to review the tests to which iron rails have been subjected. In England, Mr. Ashcroft found that the best 80 lbs. rails broke under a 300 lbs. weight, falling 15 ft. In Germany the society of railway managers determined on and have long applied a test of 1,000 lbs. falling $10\frac{1}{2}$ ft., as the standard which all first-class iron rails must reach. In this country no inspection nor test is applied, but tests made show that iron rails from our most reliable makers, break under a 6 ft. fall of a 1,500 lb. drop—an extreme test, most of

* A paper read before the American Institute of Mining Engineers, at Philadelphia, by J. B. Pearse, Esq.

those tested breaking under a far less test; some breaking with less than a 3 ft. fall of the same weight.

Everywhere where steel has been used, engineers have come to the conclusion that some test is required to show the regularity and strength of the product. As compared with iron, the tests which steel will stand are wonderful. After numerous experiments partially based on the experience of the rail mill at Graz, belonging to the Southern Railway of Austria, the society of German railway managers fixed upon a test of 2,000 lbs. falling $13\frac{1}{2}$ ft. They found that this test represented the steel which suited their necessities, and also found that with steel of otherwise average purity, this test represented about $\frac{1}{2}$ per cent. of carbon, and made it a rule to take no steel containing under three-tenths of a per cent. of carbon, because it was too soft. They expressed a hope that a harder steel could soon be made tough enough to stand the same test. In England, a test was adopted of 2,240 lbs., falling 15 to 17 ft. on the rail on heavy bearings. This test has been found satisfactory under heavy traffic on average road-beds, and has been invariably retained by English makers, and adopted by American makers. It is an expeditious practical way of ascertaining the qualities of the rail. Experiment in Germany and experience in England pointed out the test corresponding to the proper grade of steel, and the test adopted has been considered the most practical one. The jar from a moderate weight (2,240 lbs.), falling from a great height, is more sudden than that imparted by a heavy weight falling a small distance, and better adapted to exhibit the toughness of the rail. This latter is the object had in view in all tests, as it would take far too long a time to determine the quality of rails by a treatment approximately similar to that received in the track. An objection of some force has been urged against the English method of obtaining test pieces. They take one rail from each day's rolling, to indicate the quality of the rest. In this way their test becomes a matter of chance, and nothing they have yet done removed this character. Our American practice has been to test every charge, thereby insuring beyond doubt the quality of the rails.

After a short experience with steel rails it was found that their homogeneity is their distinguishing characteristic; but they unite entire homogeneity with considerable hardness as compared with iron. There are no layers to peel off, no welds to open out, the ends of the rails do not broom out as iron rails do, and the head wears uniformly along its whole length. Not only is the single rail entirely homogeneous, but all the rails made from a single charge have exactly the same qualities. Many experiments on the steel at Seraing in Belgium, in Austria, and in this country, before and after its conversion into rails, show this to be a fact.

But the hardness is a most important point as regards wear. Some first rate English rails have been found too soft for roads with heavy traffic. Therefore, a rail is wanted which will be hard enough to stand abrasion and wear, but strong enough to stand all the strains to which it is liable. The railroad engineer's idea of hardness is that quality which imparts durability without brittleness. Hardness is sometimes erroneously associated with brittleness because some hard bodies are brittle, but in steel brittleness arises from causes entirely different from those which produce hardness. The steel maker's idea of hardness is a composite one — one that results from considering the effects of physical structure or grain of the steel, and the effects of carbon, phosphorus, and manganese. The effects produced by the presence of these elements far exceed any brought about by change of physical structure. Phosphorus and manganese occasion brittleness, while carbon in excess is seldom present, as the processes through which the rail passes have a constant tendency to reduce it. The state in which carbon is present in the rail is, however, remarkably influenced by mechanical treatment and the resulting physical structure. Those modes of reduction which work quickly and forcibly, exert a strong influence to retain the carbon in a combined state, while the slower methods, on the contrary, permit some of the carbon to separate as graphite. These facts have been observed by Gruner and Caron, and have been corroborated in Austrian practice, as the following analyses of steel will show:

(*a*) Steel made for heads of steel rails at Graz, and rolled into shape without hammering:

Combined carbon	0.38
Graphite	0.65
Silicium	0.05
Manganese	0.07
Sulphur	0.05
Copper	0.08
Iron	98.57
	99.85

(*b*) Steel made at Neuberg and hammered into shape:

Combined carbon	0.234
Graphite	none
Silicium	0.033
Phosphorus	0.044
Sulphur	traces
Manganese	0.139
Copper	0.105
Iron	99.445
	100.00

Both these steels were soft Bessemer steel, and from observation I made at the two works on the respective quality of their metal, I see no reason to doubt their correctness. A remarkable point in the matter is that their iron at Neuberg was much more graphitic than that used at Graz. At Neuberg they tapped direct from the blast furnace, and their "blows" averaged about 30 min., some running up to 50 min. At Graz they remelted their iron in an air furnace, and their "blows" were much shorter. The iron each works used was then of substantially the same character, made by charcoal from spathic ore. Neuberg made its own iron, while Graz bought its iron largely from Mariazell and Eisenerz, furnaces not far from Neuberg.

Now, at the Pennsylvania Steel Works we have a quite graphitic mixture, for conversion, but we find scarcely any graphite at all in the rails—in fact none. Out of many tests we have only one, an apparently abnormal one, in which the graphite amounted to 0.08 per cent., it being generally present in too small quantities to be estimated.

Speaking within the limits of steel manufacture, it is safe to say that brittleness has nothing to do with the mechanical treatment, yet by this treatment the state of the carbon may be controlled and the specific gravity and consequent density of the steel increased. Rails are brittle when too cold-short from the presence of phosphorus and manganese. The proper proportion of the former forms the most delicate point in steel making, and must always be kept within safe limits. No good steel rail has ever yet been made with more than 1-5th of 1 per cent. of phosphorus, and half that is considered too much by Bessemer. In regard to manganese, our experience is not yet fully ripe. Its action, however, is far less dangerous than that of phosphorus, and in small quantities is beneficial.

We have thus a definite idea of the important qualities of steel rails and the proper tests to show their uniformity. The tests made on the steel preclude possibility of brittle steel being used, and it is evident that those methods of reduction which unite the greatest hardness with the necessary strength are to be preferred. In general terms, a steel rail is wanted to last a lifetime, and be strong enough to stand all accidents of wear.

Rail-making begins with the Bessemer ingot. This is a block of highly crystalline metal, the tensile strength of which is low, and which contains some blow-holes or bubbles formed by the carbonic oxide retained by the liquid steel. The inner surface of these bubbles is generally oxidized, and they are apt to be more numerous near the surface of the ingot.

The first steel rails made 10 years ago were treated like cast steel. Until 1863 they were made from ingots 7 to 8 in. sq. and 4½ ft. long in 4 heats. In the first 2 heats the ingot was hammered down to size, one end at a time, and swaged in dies to the shape of the first pass of the rolls. Then the bloom, by this time 8 ft. long, was rolled in 2 heats through 12 passes into a finished rail.

This process was excessively crude, wasting everything a steel-maker cares to save, and as the rails were found deficient and their weak points tested, it was found that the small size of the ingots and the little work done on them caused a great number of imperfect rails and a very poor quality in the steel. At this time the expressions of want of confidence in Bessemer steel took shape. We have now, however, surmounted all difficulties, and produced a reliable uniform quality of steel in enormous quantities, considered in the light of former capabilities of production. We now use very large ingots, which necessitate thrice the work formerly applied. In 1867 the ingots were raised in England to 10 in. sq., and in 1870 to

12 in. sq., which is the size in general use. In America we have had exactly the English experience with small ingots, the efforts to use them to advantage having entirely failed.

Seeing, then, that large ingots weighing $\frac{3}{4}$ of a ton, and making 2 rails, have been found necessary, it has become a question as to what mode of working them up gives the best results. I think that hammering furnishes the preferable product, and my present experience goes to justify the opinion. Rolling is preferred by some makers because it is thought cheaper, but I think the better wear of a hammered rail is a strong point in its favor. Rolled rails are generally softer than hammered rails, for the reason I have given—namely, because their carbon is apt to be partially separated as graphite, and their density is less.

There have been, in the history of iron metallurgy, two noted contests between rolling and hammering, in one of which the hammer came off victorious, in the other the rolls. I refer to the manufacture of hammered iron and to that of armor plates. Hammered iron is a necessity for smith work, and the qualities imparted to it by continued piling and hammering are wonderful as compared with ordinary iron. The reputation of the Low-Moor and Yorkshire iron tyres and plates is world-wide, and the steel tyre had in the Low-Moor tyre for some time a formidable competitor. In this case the benefits are produced by a better texture of the iron and greater ductility developed by the work done. The cinder is thoroughly expelled in the blooming and first piling, and may be left out of the question. In the other case the object was to get as soft and wax-like an armor plate as was consistent with the strength necessary to resist the impact of the shot. As the work done by the shot generally used represents in foot-pounds the effect of 1 (gross) ton falling $1\frac{1}{2}$ miles, it will readily be acknowledged that there is little similarity between the case of an armor plate and a steel rail, which has to stand a ton weight falling only 17 ft.

In my own experiments on the effects of the two processes, I compared ingots of the same steel with an average area of respectively about 75 and 110 sq. in., average section, as they were the only moulds I had at the time to compare. I found that the rails made of blooms, hammered from the ingots of the latter section, stood over 100 per cent. more than the rails made direct from the ingot. The bloom was hammered to the size of the ingot, and each rolled in two heats, one of them a wash heat, into the same kind of rails. I tested in this way 31 different charges. Weight used was 2,000 lbs.; bearings, 2 ft. apart. The rails from ingots stood $21\frac{1}{2}$ ft. fall of this weight, showing $1\frac{6}{10}$ in. deflection without breaking. The rails from the blooms stood a 43 ft. fall of the same weight without breaking, and showed a deflection of $3\frac{9}{10}$ in. This leaves a surplus of 50 per cent. in favor of the hammered rail, deducting 50 per cent. for amount due to difference of area of ingots. To show the connection on a manufacturing scale, of these tests with the actual result, I would remark that we made 13,285 rails out of the ingots of 75 sq. in. average area. Of these there were rejected by the railroad, for insufficient strength after delivery, 178 rails, or $1\frac{1}{3}$ per cent. Of the larger ingots we had made up to the fall of 1870 —34,320 rails, and had rejected for all causes, after delivery, only 18 rails, or $\frac{1}{20}$ of 1 per cent., or a quantity only $\frac{1}{26}$ as large as before.

We therefore continued to hammer, but now use an average section of 150 sq. in.; doing $\frac{2}{3}$ the work under the hammer, and only $\frac{1}{3}$ in the rolls. Our rails thus produced stand a ton weight falling $17\frac{1}{2}$ ft., and leave an ample margin of reserved strength. We have had recent tests, in which the rail stood what was equivalent to a ton weight falling 70 ft., without breaking, but have not yet got up to the armor plate standard of a mile and a half. Out of a lot of 1,200 tons of 58 and 60 lb. rails, not a single rail, out of the 439 tests given, broke under a ton weight falling $16\frac{1}{2}$ ft. We have since had many similar series.

The bubbles in the ingots give some trouble in the subsequent working, sometimes occasioning cracks in the ingot requiring to be chipped out. This we do, as we hammer the ingot down, without hindering the hammer in its work. Rolls are apt to laminate these bubbles instead of forcibly compressing them, like the hammer, and it sometimes happens that the bubble breaks out on the surface of the bloom and causes a long streak where the metal is not sound. These streaks are especially noticeable in the head of the rail. In order to obviate the cracks resulting from these blow-holes, a hammer must be associated with the rolls to chip out bad places; and this renders the rolling process more complicated than it would appear at first sight. I do not see why it is not simpler to do all the work under one tool, viz., the hammer.

The objections to hammering on the score of cutting sharply into the metal, are not, in my opinion, of weight, as our experience agrees with the English, that you can hardly have too heavy a hammer for steel. We can strike 2 full blows of a 12-ton hammer on the same place without deforming or injuring the bloom in any way, or making a mark on it deeper than $\frac{3}{8}$ in. each time. As showing what steel will stand, I will say that I have seen, in Vienna, Haswell's hydraulic press reducing ingots from 10 in. thick to 2 in., at one squeeze, without injuring the steel, which was from Neuberg. It is thus surely idle to talk of a hammer as injuring steel in any way. The stroke of a heavy hammer works uniformly through the bloom, drawing the interior as much as the surface. We want to make a hard and tenacious bloom, and the concentrated blow of a heavy hammer is well adapted to that end. We lose practically nothing in ductility as compared with the rolls, and have ample room within the limits of our strength. The chemical composition controls the brittleness of our rails, and as long as we keep that right we can make a comparatively hard rail, well adapted to wear.

In regard to the amount produced by the two methods in the same time, the hammer compares very favorably with the rolls. A blooming mill turns out about 55 tons of blooms a day from ingots. We do as much as that daily under a 12-ton hammer, and have done much more than that for a considerable time, so that the relative capacity of the two is hardly decided as yet. In 5 to 6 min. we can hammer down, chip, and cut in two, and carry away a large ingot reducing it to $\frac{1}{3}$ its former size; and in 35 to 40 min. do the w.ole work of getting a heat of 5 ingots hammered complete into finished rail blooms requiring no subsequent hand-chipping. For 3 months this hammer did an average of about 70 tons of rail blooms per day, turning them out sound and well chipped.

As a matter of interest, it may be well to refer to the fact that at Neuberg, in Styria, they use a 19-ton hammer on steel, and, according to published statements, produce under it in a week only 65 tons out of 2 furnaces in $11\frac{1}{2}$ turns. They hope, by using 4 furnaces, to get up to 130 tons a week. It shows well the spirit of American work to compare our product with this. We do now over 3 times as much as they hope to do, and do it under a hammer of under $\frac{2}{3}$ the weight. The weight of ingots is about the same.

I have explained above my reasons for preferring hammered rails, all derived from experience capable of easy verification. In practice we have found, as far as we could compare hammered with rolled rails, that the former stand the treatment they have to suffer better than the rolled rails. From experience with rails of different making, rolled and hammered from ingots of the same size, I am enabled to say that the hammered ones have far less rejections on all accounts than the rolled ones, and that their strength against sudden jar is greater.

I believe, therefore, that the hammered rails are superior to the rolled in very important characteristics. I do not deny that rolling may be improved so as to equal a hammered rail. That is not impossible or improbable. It has not done it yet in my opinion, but when it does I shall be most happy to change my opinion.

In order to show the relative endurance of iron and steel rails, I would like to mention a case that may be regarded as furnishing an American experience of steel rails, equalling that had on the English railroads. and especially on the London and Northwestern. The Philadelphia, Wilmington, and Baltimore Railway laid in their yard in Philadelphia, steel rails on one side of the track and iron rails on the other. The steel rails were hammered rails, and were, with the iron, laid in 1864. The steel rails wore out some 17 sets of the iron rails, and then the Company stopped the experiment, laying steel on both sides.

On a curve of 525 ft. radius, steel rails have lasted intact since 1865, and are as perfect as when laid, where iron rails had before lasted only from 3 to 6 months.

None of the rails of the Pennsylvania Street Company, nor of any other company in this country, have ever been worn out by traffic or shifting work, so that I can, after a five years' experience of American makes, have reason to believe they will last at least a generation, under the hardest service.

PREVENTION OF BOILER INCRUSTATION.

From "The Mechanics' Magazine."

At the Vienna South Station important experiments are being carried on with feed-water according to M. Bérenger's suggestion. The process consists in softening the water by a solution of lime, and forcing the liquid, which holds the generated precipitate in suspension, through a particular kind of filter. There is no necessity to wait for the settling of the precipitate. From 10 to 15 filters, each of 0.1 cubic metre in capacity, soften about 410 cubic metres of water per day. In 10,000 parts of water, according to analysis, there are contained

	Before softening.	After softening.
Common salt	0.8029	0.8237
Chloride of magnesium	0.2986	0.2892
Gypsum	1.9398	1.6796
Carbonate of lime	1.8830	0 0292
Carbonate of magnesia	1.4729	0.0178
Silicic acid	0 0715	0.0580
Organic substances	1 9853	1.4370
	8 4540	4.3345

Protracted boiling produced in 10,000 parts of unsoftened water a sediment of 3.3510 parts, consisting of

Carbonate of lime	2.3420 parts.
Carbonate of magnesia	1.0090 "
	3 3510 "

In 10,000 parts of softened water, a sediment of 0.0305 parts was found, consisting of

Carbonate of lime	0 0265
Carbonate of magnesia	0.0040
	0.0305 parts.

The hardness of the unsoftened water, tested by soap solution, was 26 deg.; that of the softened water 8.5 deg. Before being softened, the feed-water produced at times magnificent specimens of incrustation. Some of these were analyzed. They were found to consist of layers of several inches in thickness, having a bluish-gray color. These products contained in 100 parts the following:—

Carbonate of lime	73.87 per cent.
Carbonate of magnesia	19.40 "
Gypsum	2.29 "
Oxide of iron and alumina	3 07 "
Silicic acid and sand	0 83 "
Water and organic substances	10 93 "
	100.39 "

The sediment produced by softened water, on the other hand, consisted of a loose yellow powder, which after 6 months' use of the boiler was taken out. One hundred parts of this muddy substance contained:—

Gypsum	70.60 per cent.
Organic substances and water	18.23 "
Carbonate of magnesia	1.57 "
Carbonate of lime	1.41 "
Chloride of calcium	0 07 "
Sil cate of lime	0 65 "
Ferric oxide and alumina	1.52 "
	100.05 "

The precipitate formed by addition of lime water is retained in the Bérenger filter. One hundred parts of this precipitate contain:—

Carbonate of lime	69 71 per cent.
Carbonate of magnesia	10.96 "
Gypsum	7.92 "
Silicate of lime	0.63 "
Ferric oxide and alumina	3.46 "
Water and organic matter	5 57 "

From the above it is plain that, by this process of softening, the carbonates of lime and magnesia are almost entirely removed, and also part of the gypsum. The quantity of silicic acid and organic matter is also considerably diminished. If there be a large quantity of gypsum in the water, it is best to precipitate that by the carbonates of lime and magnesia, and part of the gypsum dissolved in the water, saturated with carbonic acid. By a subsequent addition of soda the remainder of the gypsum and muriate of magnesia, as well as occasional traces of chloride of calcium, are changed into carbonates of alkalic earths.

REPORTS OF ENGINEERS' SOCIETIES.

THE POLYTECHNIC CLUB.—At a recent meeting of the Polytechnic, the following pertinent discussion was offered on the "Ellis Bi-Sulphide of Carbon Engine." We make the extract from the columns of "The Engineering and Mining Journal."

DR. VAN DER WEYDE.—Mr. Ellis, of Boston, has lately constructed a Bi-Sulphide of Carbon Engine, using the waste steam from the engine to heat the bi-sulphide of carbon, and work another piston attached to the same engine. There have been two objections made to this, which I wish to answer. One objection is that we might just as well have 2 steam cylinders, making a compound engine, the steam from a high-pressure engine working a low-pressure engine. The other objection is, that if we are to use the bi-sulphide of carbon, we do not need the steam, and I will reply to this objection first. Volatile substances require very little heat to convert them into vapor. Water requires a temperature of 212 deg. to vaporize at atmospheric pressure, and 966 units of heat become latent. But ether will vaporize at 96 deg., and only 165 units of heat are required. That is an immense saving of fuel. On that idea, some 15 years ago, an ether engine was built at the Novelty Works, New York. But practical difficulties came up. First, it was difficult to get the joints tight; and when it leaked it took fire, and alarmed every one. Another difficulty was, that the latent heat was so much by weight, and the vapor of ether is nearly seven times as heavy as steam. It is a curious property of vapors, that whatever the temperature of vaporization, and whatever amount of heat becomes latent, in units, the amount of latent heat in a cubic foot of vapor, is always the same; and as engines are driven, not by the weight of the vapor but by its volume, that takes away all the supposed advantage of volatile fluids with regard to their latent heat.

The first objection was, that we might as well use the team from a high-pressure engine to drive a low-pressure engine. The simple answer to that is, that all the pressure you get from the waste steam becomes back pressure on the first engine, and you have all the machinery and friction for nothing. But if you pass your waste steam freely through tubes which heat bi-sulphides of carbon, there is no back pressure, and the pressure you obtain from the vaporization of the bi-sulphide of carbon, is a clear gain. Fairbank & Dunkin in England founded a method of judging of the performance of steam engines, by measuring the water of condensation, as it was done in the recent trial at the American Institute Fair. In the best steam engine, the water of eondensation is warmed somewhat, and that amount of heat is lost. Now let us see what is the pressure with different vapors:

Ether.	Bi-Sulphide of Carbon.	Water.	Pressure.
95 dgs.	110 dgs.	212 dgs.	1 atmosphere.
115 "	130 "	250 "	2 "
125 "	140 "	276 "	3 "
133 "	148 "	291 "	4 "

Now if we take the steam at 212 deg., you see that it will produce a pressure of much more than 4 atmospheres in the bi-sulphide of carbon. It is asserted that by this engine, a nearer approach has been made to theoretic perfection, in the power produced, than ever before.

Another point. In heating water from 212 deg. to about 248 deg., you double the pressure; so that at least 2 deg. are necessary for every pound of additional pressure. But if you heat it to 500 deg., where the pressure is 50 atmospheres, then 15 deg. will produce 15 atmospheres more pressure, or a whole atmosphere for every degree. Here we have to keep the water at 500 deg. and upwards; but there are other liquids that do not require that temperature. Take the liquefied carbonic acid gas, which boils at 148 below zero. Heat it to 100 deg. below zero, and you have 2 atmospheres pressure; an additional atmosphere for about 48 deg. But heat it to 32 deg. and you have 32 atmospheres; and at 50 deg. you have 50 atmospheres, making a whole atmosphere for every degree. It is only necessary, then, to maintain the ordinary atmospheric temperatures, and in the summer all you have to do is to heat with the atmospheric temperature, and to cool with ice. Your engine will require no coal. But you will have this drawback, that melting ice only consumes 140 units of heat, whereas the combustion of coal gives out 14,000 units of heat. For every pound of coal, therefore, you will want 100 lbs. of ice; and ice is not so easy to keep, especially in the summer, as coal. Another difficulty is that the boiler must be strong enough to stand 50 to 65 atmospheres of pressure. Of course, this whole plan is intensely absurd; but as Cicero said that no theory was so absurd that no man would adopt it, so in mechanics, no plan is so absurd that no one will try to carry it out; and there is a young gentleman now endeavoring to carry out this plan. He will have a back pressure of 50 atmospheres on his piston—a very respectable back pressure.

INSTITUTE OF MECHANICAL ENGINEERS.—At the meeting of the Institution of Mechanical Engineers held at Birmingham on the 25th ult., a paper was read "On the Strength and Proportions of Riveted Joints," with the results of some recent experiments, by Mr. Walter Browne, of Bristol. In this paper four different modes of fracture possible in riveted joints were described, consisting in—shearing of the rivet—crippling of the plate, or elongation of the rivet hole in the line of strain—fracture of the metal between the rivet hole and the edge of the plate, in the line of strain—or tearing of the plate along the line of the rivet hole, at right angles to the line of strain. From the consideration that a perfect joint would be one offering equal resistance to each of these modes of fracture, the proper proportions were deduced for the various descriptions of riveted joints, with the aid of data furnished by different experiments previously recorded, and by a series of experiments recently made for the purpose by the writer. The proportions thus obtained for single-riveted lap-joints are that the diameter of the rivets should be twice the thickness of plate, and the pitch of the rivets and the width of the lap should each be three times the diameter of the rivets. For double-riveted lap-joints, the diameter of the rivets being again double the thickness of plate, the pitch should be 4½ diameters, and the width of the lap should be 5¼ diameters in chain riveting and 6 diameters in zigzag riveting. For butt-joints with a single cover-strip the proportions are the same as for lap-joints; and with double cover-strips, the thickness of each strip being only half that of the plates, the diameter of the rivets should be $1\frac{1}{4}$ times the thickness of plate, and in single-riveted joints the pitch should be $3\frac{1}{4}$ diameters and the width of the cover-strips 6 diameters; in double-rivetting, the pitch should be 5 diameters, and the width of the cover-strips 11 diameters in chain riveting and 12 diameters in zigzag riveting.

A calculation of the proportionate strength of these different joints, as compared with the strength of the solid plates themselves, shows that but little advantage is obtained by the employment of butt joints in place of lap-joints, so far as mere strength of joint is concerned; and even in the best instance the strength of a double-riveted butt-joint with 2 cover-strips and drilled holes is less than $\frac{4}{5}$ of that of the plate, while in common single riveted lap-joints with punched rivet holes the strength is little more than half that of the plate, thus involving practically a serious waste of material. In the case of cylindrical boilers, constructed with the ordinary longitudinal and transverse joints of the plates, the strain produced upon the longitudinal joints by the internal pressure of steam is double that upon the transverse circular joints; and two modes of remedying this inequality in the strength of the joints have been adopted. The first consists in arranging the joints diagonally, in spiral lines round the boiler, whereby the effective strength of the joints and of the boiler is increased in the ratio of 4 to 5.

In the other plan the boiler plates are rolled with thickened edges along the longitudinal joints, by which means and by double-riveting the longitudinal joints, the strength of the joints is brought up very nearly to that of the solid plates themselves without the necessity either of butt-jointing or of drilling the rivet holes; the thickened edges have also the advantage of obviating the ordinary corrosion occurring at the joints, which is so fruitful a source of boiler explosions. The importance of the subject investigated in the paper is sufficiently shown by the serious consequences which have arisen from defective construction of joints, both in boiler work and in iron shipbuilding.

AMERICAN INSTITUTE OF MINING ENGINEERS. —*Proceedings of the Fourth Quarterly Meeting, Concluded.*—The Institute met according to programme, on Wednesday evening, the 21st, for its second session, the day having been spent by the members and associates in visits to various points of interest. The large magic lantern of the Franklin Institute was kindly lent for this occasion.

Mr. Benjamin S. Lyman exhibited upon the screen an excellent view of the famous iron column at Delhi, from a photograph which he had brought with him from India. This column has been recently described in the London "Engineer." Mr. Lyman having frequently seen it, his statements with regard to it were eagerly listened to by the metallurgists present. He believed the column to be of wrought iron, and suggested that the expression "mixed metal," in the report of the Archæological Surveyor to the Government of India, might refer (if it means anything) to some apparent impurity or imperfect reduction of the iron. The column is 22 ft. high above ground, 16.4 in. in diameter at the ground, and 12.05 in. at the top. It is said to extend at least 26 ft. below the surface of the ground. The inscription upon it indicates by its Sanscrit characters an antiquity of 1,500 years or more. The popular legend concerning it, that it was driven into the earth by the last ruler of the Hindu dynasty, at the suggestion of his soothsayers, to pierce the serpent who lies coiled beneath the world, is not corroborated by the inscription, which commemorates the glory of one Dhara, of whom nobody now knows anything. It is noteworthy that the popular legend expresses no sense of anything unusual in the material or mode of manufacture.

After this, a paper was read by Dr. Thomas Downe upon a new testing machine for metals.

Next followed a paper by Mr. A. L. Holley on Rolling Mill Machinery.

The first paper of the third day's session was prepared by the President, but was read in his absence by Prof. Maynard. The subject was the Anthracite Furnaces of the Lehigh Valley.

U. S. Commissioner Raymond read a paper on a new electro-magnetic separator, the invention of Mr. Balch, of Baltimore.

The next paper was by Mr. S. H. Daddow on Pillars of Coal.

A paper by Mr. Loiseau on the "Utilization of Coal Dust as Fuel," was next read. This was followed by a paper by Maj. T. B. Brooks on "The Methods of Extraction employed in the Iron Mines of Lake Superior."

A paper by Prof. Thomas Egleston on the "Utilization of Furnace Slags" closed the morning session.

The papers of the evening were as follows:

"On Exploring for Iron Ore," by Maj. T. B. Brooks.

"Blast Furnace Fuel," by Mr. S. H. Daddow.

"Surveying in Geological Work," by Mr. B. S. Lyman.

The resignation of the President of the Institute created a vacancy, which was filled by the election of R. W. Raymond, U. S. Commissioner of Mines, and Vice-President of the Institute. Mr. R. P. Rothwell was thereupon made Vice-President to fill the new vacancy.

At the close of the discussion, the President briefly congratulated the Institute upon the unmistakable success of its first four quarterly meetings. The character of the papers presented, the vigor and good temper of the discussions, and the great social enjoyment and professional profit which all all have derived from the meetings, have been so many pledges of the future prosperity of the Institute.

No one has been urged to join the Institute; its doors are open to the profession and to the public interested in its objects; but it is not a beggar for members or associates. Assured in its vitality and progress, it is assured also in the expectation that the mining engineers and metallurgists of the country will gather around it, not for its sake, but for their own.

The Institute then adjourned, to meet again in May, at such place as shall be announced by the Council.

IRON AND STEEL NOTES.

TESTS OF DANK'S ROTARY PUDDLER AT THE AMERICAN IRON WORKS.—We last week gave extracts from the report of the English Commission sent to this country to examine the workings of this furnace. The following extract from "Statement No. 11" will interest our readers:

Jones, Laughlin & Co., Pitts. Mr. Jones very kindly had the furnace put in order and worked a few heats specially for us, from American iron of various classes. The results obtained were:

1st Charge—"Douglas iron" gray pig, from ⅔ Lake Superior, ⅓ Lake Champlain ore and raw coal; pig, 520 lbs.; bloom made under hammer, 520 lbs.. 210 lbs. of this charged into heating furnace gave 196 lbs. merchant bar.

2d Charge—"Eliza iron" mottled and close gray, made from all Lake Superior ore with coke. Charge put in at 10.45, brought out at 11.55. This ball was too hot in the centre, and cold on the outside, and went to pieces under hammer.

3d Charge—"Douglas iron." Mr. J. A. Jones caused this heat to be worked in a slightly different manner, whereby the quality was much improved, but the yield was not so good—515 lbs. pig gave 433 lbs. hammered blooms. The iron from this heat stood the most severe hot and cold tests admirably.

From the books of the Company we extracted the following results of charges worked in the rotary furnace:

RESULTS.	Charges.	Pig Charged.	Hammered Bloom.	Iron Turnings.	Ore.
April 8	6	4,200	4,305	115	600
" 21	6	4,220	4,270	310	715
" 22	4	2,825	2,792	135	742
" 24	5	3,540	3,771	*	485
" 25	5	3,600	3,722	160	800
" 26	6	4,240	4,127	235	762
" 27	5	3,585	3,575	240	910
" 28	5	3,560	3,698	230	915
" 29	5	3,567	3,809	240	705
May 1	4	2,850	3,010	140	980
"	2	3,550	3.611	135	718
	56	39,737	40,690	1,940	8,332

* No turnings.

Yield per ton hammered blooms.

Pig iron ton of blooms.			Iron turnings.		Iron ore.		
cwts.	qrs.	lbs.	qrs.	lbs.	cwts.	qrs.	lbs.
19	2	3	3	22	4	0	9

—*Chichago Railway Review.*

THE ROLLING MILLS OF PITTSBURGH.—The first attempt at making bar iron in Pittsburgh occurred in 1813, particularly for the hardware trade. It was operated with indifferent success until 1845, when it was suspended. A second mill, put in operation in 1819, operated until 1829, when it was discontinued. In 1825 three mills were put in motion, and from that time until now, 26 have been erected, making 29, all except one, still in operation. One of these is now able to do as much work in one week as half a dozen were at first able to do in 3 months. The machinery employed at the close of 1871 was as follows:

Rolling or puddling furnaces	720
Heating furnaces	180
Nail, tack, and spike machines	542
Railroad spike machines	19
Steam hammers	85
Eight inch roll trains	48
Nine inch roll trains	1
Ten inch roll trains	19
Twelve inch roll trains	9
Sixteen inch roll trains	29
Eighteen inch roll trains	33
Twenty inch roll trains	47
Twenty-six inch roll trains	1
Twenty-eight inch roll trains	1
Thirty inch roll trains	1

A number of these trains are three-high, of the Louth patent. The manufacture of rolls is a large part of the iron business of Pittsburgh, one firm alone having made, during 1871, 600 rolls.

The largest of these are employed in the manufacture of plate iron for naval use, some 1½ in. thick, 4 ft. wide, and 15 ft. long. But the great bulk of the iron turned out is merchant bar and sheet, and sheet steel for boilers and saws, which finds a market in every State in the Union, the present aggregate value of which is $24,000,000.—*Chichago Railway Review.*

RAILWAY NOTES.

FRACTURE OF RAILWAY AXLES. From the official reports of the "Verein Deutscher Eisenbahn Verwaltungen," it appears that during the year 1870, on 22 lines belonging to the Association, 132 axles of locomotives, tenders and carriages, were broken. In comparison with the previous year, in which the fractures amounted to 163, those figures show an improvement. There is a decrease of 19.3 per cent. on the service, which, considering the extraordinary demands occasioned by the Franco-German war, and the increase of rolling stock in Austria, appears considerable. The fractures either occurred or were remarked in the months of

December, January, February,	in 39 cases	
March to May	(inclusive),	in 30 "
June to August	"	in 25 "
September to November	"	in 38 "

The influence of the cold season, despite much that has recently been said to the contrary, is distinctly marked; from March till August 55 only, and during the other months, 77 axles broke. The average run of the axles broken in 1870 was as follows:

Locomotivss	11	years	4	months	13	days
Tenders	13	"	4	"	20	"
Carriages	11	"	11	"	13	"
Average	12	"	2	"	29	"

The average mileages of the axles were in the case of

Locomotives	34,241.7	miles (German)
Tenders	31,494.5	" "
Carriages	24,040 1	" "
Average	27,631.1	" "

The maximum mileage attained was 69,000 miles. Since the last preceding inspection, they had run on the average as follows:

One locomotive axle	2110 7	miles
One tender axle	1795.8	"
One carriage axle	1426.6	"
Average	1677.6	"

Similarly to the results of the preceding year, the broken tender axles show a higher figure of run than the carriage axles; the explanation, probably, is to be found in the fact that the tender exles are more often inspected and sorted out. The mileage of puddled and cast-steel axles is, as in former years, less than that of wrought-iron ones, showing room for improvement. As a rule, where a fracture has commenced in a steel axle, that axle is sooner doomed than would be the case with a wrought-iron one. As far as could be ascertained, 38 per cent. of the fractures occurred at fall speed, 41 per cent. at medium speed, and 20 per cent. at rest. It is remarkable that the full speed shows a lower figure than the medium speed.—*Railway Times.*

Grand Railway Enterprise. The Peruvian Government proposes a railroad 14,000 ft. above the water. It will connect different parts of the country by railway and steamboats, the former going over the main ridge and valleys of the Andes at an elevation of 14,000 ft. above the level of the sea, or 7,000 ft. higher than the highest point of the Sierra Nevada, crossed by the Central Pacific Railroad. This elevation is within 1,000 ft. of perpetual snow. Edward H. Spaulding, of Bloomfield, New Jersey, for 4 years Assistant Engineer on the Montclair Railway, has sailed for Peru, in company with some of our best American engineers, who have been selected to accomplish this difficult undertaking. The railway goes from Peru to Arequipa, 40 miles; thence to Puno, on Lake Titicaca, 800 ft. above tide water. Lake Titicaca is partly in Bolivia and partly in Peru, and is one of the principal sources of the Amazon, which is navigable for nearly 4,000 miles. The combined railway and steamboat communication will cross the continent at its widest point. Mr. Meigs, the contractor, has had contracts in that country amounting to over one hundred millions of dollars. American styles of cars and rolling stock will be introduced on that railway.

Railways of the World.—The following estimates of the total length and cost of railways in the world, appear in the last number of the "Rev. Ind.:"

	Kilometers.	Francs.
Europe	97,660	41,261,950,000
America	89.959	12,163,450,000
Asia	7,158	2,073,915,000
Africa	932	274,685,000
Australia and Polynesia	1,974	501,005,000
	189,691	56,274,500,000

or a total of 119,871 miles and nearly 2,251 millions sterling. The average cost per mile, resulting from the foregoing, is £19,097, varying in the different continents as follows: Europe, £36, 863; America, £9,421; Asia, £18, 397; Africa, £18,718; and Australia, £12,922. The length of railways in operation in France is stated at 11,185 miles, about 10 per cent. of the grand total, and 18 per cent. of the European net work.

ENGINEERING STRUCTURES.

New Railway Bridge at Albany.—The new railway bridge over the Hudson at Albany, N. Y., begun in June, 1870, has lately been completed. The main bridge is 1,525 ft. long from Quay street to Van Rensselaer island, and the whole length, including approaches, 2,250 ft. It is 30 ft. in the clear above low water mark of 1857. There are two bridges above Van Rensselaer creek (the first comprising three spans 62 ft. 6 in. each) one connecting with the New York and Boston railways, and the other for Troy local trains. The portion of the bridge across the basin descends 3 ft. from the pier to Quay street. The trusses in the superstructure are 26 ft. apart. All the tension bars of the bridge are of double refined iron, and it is calculated that the brige will stand a load of 6,000 lbs. per lineal ft., exclusive of the weight of the structure, the strain of which will not exceed one sixth of the breaking weight. The draw weighs 350 tons, and is to be worked by a ten horse power engine placed beneath the roadway. Clark, Reeves & Co., of the Phœnixville Bridge Works, Phœnixville, Pa., were the contractors for the superstructure.

Housatonic River Bridge.—The new iron bridge over the Housatonic river at Stratford, Conn., on the New York and New Haven Railroad, is completed. This bridge is one of the handsomest in the State. It was commenced in March, 1871, and has been pushed, in spite of the cold weather of the early winter, to completion in a wonderfully brief time. The bridge is 1,091 ft. long, 27 ft. wide, with two tracks, and the height of the iron work is 24 ft. It has five spans, three on the east side of the draw and two on the west, and the draw is 206 ft. long. Five piers and two abutments of solid masonry support the iron work of the spans; and the height of the piers, except the draw pier, is 36 ft. 8 in., they being 7 ft. wide at the top and at the bottom. The draw pier is 30 ft. wide at the top and 35 at the bottom, and rests upon 427 piles, sawed off by divers, level with the river bottom. Total cost, about $300,000. The contractors were F. C. Lowthorp, of Trenton, N. J., patentee; John Beattie, of Stony Creek, stone work; S. A. Hammond, of Bridgeport, piling and timber work, and George Everett, of Allentown, Pa., superintendent of the iron work. The frame work of cast iron came from Birmingham, Conn., and the tension rods from Trenton, N. J.

The Channel Tunnel.—In a letter to a Glasgow contemporary on this project, Mr. John G. Winton, C. E., F. R. S. S. A., of Portobello, writes:—I have long ago pointed out that this tunnel cannot be cut without providing exhausting machinery for promoting ventilation. Messrs. Hawkshaw and Co. do not consider this neccessary.

Now, I say it is imperative, both as regards driving the tunnel and effecting a thorough ventilation when in working order. Thus, these four engineers have failed in the preliminary steps. Their study of the scheme is marked at the very outset with a want of forethought. Their driftways are to be about 9 ft. square—this is simply the precautionary subways, and which are to be enlarged into one tunnel; but mark, not until the preliminary driftways are cut from shore to shore. My study of the matter points out a very different mode of action. The "twin tunnels" will be about 16 ft. in diameter, and about 25 ft. from centre to centre; thus the mid-wall between the tunnels will be 9 ft. in thickness. I take no preliminary steps after once knowing the character of the material, and which knowledge can only be acquired by piercing the strata for a considerable distance at each shore. No one would ever think of commencing such a work of vast magnitude without taking precautionary steps. Once decided on, I propose to cut and line up, as the work proceeds. My "long wall" method of working, with tunnels 16 ft. in diameter, is the only way of securing a good and lasting structure, taking into consideration that a single tunnel for double rail will be at least 24 ft. wide; this does not include the breadth of excavation necessary for the lining material. If in my "twins" cast iron must be adopted for lining up, each excavation will only be 16 ft. or so in diameter; thus a great deal of unnecessary excavation and material for lining up is saved with the twin system. And with the method I adopt for ventilation, locomotion can at all times run up to the headings, and by the system of cross shunting subways the spoil can be rapidly taken away, and the building material brought in.

The Suez Canal—A correspondent writing from Paris says: It is well known that since the opening of the Suez Canal to heavy navigation, the tolls have been levied from the tonnage officially registered on each ship's papers. Now, it has been recognized since the canal was first worked, that the majority of vessels traversing the canal carried an amount of freight largely in excess of what is stated in the papers. The interests of the shareholders suffer from this, and the administration of the Company has just appointed a commission to decide whether it will not be expedient to change the mode of operation. The commission had to ascertain what should be included according to the statutes in the tonnage capacity, and the best means of estimating the screw for each vessel. After a preliminary private discussion, these questions were submitted to a sub-commission, whose report was delivered on the 8th of November last. We believe that the conclusions of this report are as follows: The tonnage capacity is indicated by the act of concession at the volume of 1.44 cube metres applied to that portion of the ship that can be utilized of the cargo. We must remember that the modifications made in the old rules of gauge have for their object to determine the maximum tonnage without attempting to express truly the capacity, and the sub-commission think that the Company ought to establish its taxes without being guided by the official statement, arriving at the useful capacity estimated from the total capacity of the ship, and determined as equitably as possible, according to the actual condition of the load. The total capacity in tons of 1.44 cube metres being approximately double the gross tonnage calculated according to the English gauge, the amount to tax for steam vessels will be half the total capacity, and will be established on the same amount of gross tonnage. For sailing vessels it will be 0.65 of the total capacity, and will be established on the amount of tonnage 1 plus 30 per cent. The effect of these new regulations, combined with the tariff of 10 francs per ton which bear on the receipts of the Company, will be duly appreciated. Not to speak of sailing ships, steam vessels pay to-day according to their net tonnage. Considering especially English ships, which form the large majority of vessels passing through the canal, the proportion of net tonnage to gross tonnage is as 70 to 100. The receipts would thus increase this proportion—that is to say, the augmentation would be 47 per cent.

The St. Louis Bridge.—The progress of work on the superstructure is described as most gratifying. The masonry, which has been delayed by the unusuallysevere winter, is now, the "Republican" states, being pushed with t e utmost vigor. All the granite is on hand, and the Company expect to have the masonry all completed within 4 months.

Capt. Eads is at the East attending personally to the rapid prosecution of the steel-work, and the results of operations at Pittsburgh and Philadelphia are very encouraging. The Butcher works turn out 40 steel staves a day, with the complement of steel pins, nuts, tension rods, etc. The average weight of the staves is about 600 lbs. each; they are about 12 ft. in length, 2 in. thick, and 6,000 will be required. One thousand are now finished. Each tube consists of 6 staves, and they will be put into the tubes like the staves of a barrel, with sheets of steel around them. There have been 20 tubes put together in the yards of the Keystone Bridge Co. In addition to the steel-work, the wrought iron beams, brace bars, etc., are being turned out in large quantities, and iron bridges over Main and Second streets will soon be completed.

The torpedo boat to be built at Boston promises to be a very formidable engine of war. It will be about 170 ft. long, 35 ft. wide, and 15 ft. deep, and draw about 12 ft. of water. It will be of 350 tons burden, with two powerful propelling engines and two propeller screws. The prow of the boat is to be made sharp, and will carry a steel ram 6 ft. under water. Above the ram there will be an aperture through which will pass a long composition spar, on the end of which will be placed a torpedo of the most approved pattern. The boat will be heavily plated on the sides with iron 6 in. in thickness, while the decks are to be protected by steel plating, one inch in thickness. The estimated cost of the vessel is about $300,000, to which may be added about 50 per cent. for extras and items not counted in the estimates. Such a vessel might, perhaps, be useful in the event of war, but even then its utility would be very doubtful. It is designed to operate against blockading fleets, and, as blockades are obsolete, we doubt very much if it will ever prove more than a costly and interesting ornament to our now very harmless and inoffensive naval armament.

BOOK NOTICES.

TREATISE ON TERRESTRIAL MAGNETISM. (Blackwood and Sons.) For sale by Van Nostrand. The first half of this book contains a good deal of information, and some inquiries connected with the question of the secular variations in the magnetic elements. The author, on the supposition that the secular changes in the declination are caused by the action of a single, slowly-rotating pole on a needle which at each place is locally influenced in a definite and determinable manner, computes the declination at several places, and shows that it agrees tolerably well with actual observation. The rotating pole he places at a constant distance of 23 deg. 30 min. from the pole of the earth's axis, and gives to its rotation a period of 640 years. The latter part of the book, however, is taken up with "an hypothesis." The writer of this book, and many other such writers, would do well to remember the words of Newton, "*Hypotheses non fingo.*" The hypothesis referred to is simply this:—that the sun attracts the electric matter in the earth and carries it round in a sort of tidal wave; this causes an electric current from east to west, which causes the magnet to point to the north, and from which the writer also attempts to deduce some of the other phenomena of magnetism. There seems to us to be some ambiguity in the writer's method of expression, so that we do not clearly gather whether he intends this current to account for the whole magnetic action of the world, or only for the variations of it. A consideration of the character of the variations of the needle is sufficient to overthrow the hypothesis announced by our author. The solar diurnal variation is thus explained by him: The pole of the ecliptic revolves once a day round the pole of the earth's axis, the needle tends to follow this, and hence the solar diurnal variation. Now, we may point out a circumstance which, apparently, entirely overthrows, not only this hypothesis, but any which attempts to account for that variation by anything of the nature of the movement of a magnetic pole. At Point Barrow the needle points N.E., at Port Kennedy it points S.W., yet at each place the solar diurnal variation follows local time and exhibits precisely the same features. Standing, then, at the centre of the needle, and looking towards its marked end, that end would at both places be observed to be moving towards the left hand of the observer between the hours of 8 A.M and 1 P.M. But since the needles are pointing in opposite directions, this constitutes a movement of the marked end of the one towards the geographical west, and of the marked end of the other towards the geographical east, and this at times when the needles are under precisely the same circumstances with respect to the sun's influence. Now, no movement of the magnetic pole can account for this; it would necessarily entail a movement of the marked end of both these needles in the same geographical direction. The consideration of this phenomenon shows us that if the solar diurnal variation of the declination is to be attributed to a current, it must be one not round the magnetic pole or the geographical pole, but along the magnetic meridian. But this is not the place for us to discuss this question further at present. It would seem to be, however, rather from the consideration of such phenomena as this in a careful and accurate way, and the attempt therefrom, by induction, to arrive at laws, that we may hope to form a theory of terrestrial magnetism, than from "making an hypothesis," and then attempting to apply it to facts.—*Nature.*

QUEEN CHARLOTTE ISLANDS: A Narrative of Discovery and Adventure in the North Pacific. By FRANCIS POOLE, C.E. Edited by John W. Lyndon. (London: Hurst and Blackett, 1872.) For sale by Van Nostrand.

Mr. Poole enjoys the distinction of being the only educated Englishman who has ever lived on Queen Charlotte Islands, where he spent two years in an endeavor to develop the mineral resources of the country. The volume therefore necessarily possesses the interest attaching to a narrative of a residence in an almost unknown country. We miss, however, those touches which add so much to the charm of books of travel, which indicate that the writer has visited many men and many cities, and is capable of contrasting the natural products or the habits of the people of one part of the world with those of another. The attraction for the author to these islands was the presence of copper, to work which a company was formed in 1862. There can be little doubt that copper-veins, and probably other minerals, do exist in the islands in quantities that would amply repay the investment of labor and capital in their working. The climate appears to be equable and agreeable, the harbors are magnificent, and the soil is rich and productive, so that we may hope that at some future time Queen Charlotte Islands will become a valuable dependency of the British Crown. If Mr. Poole's volume succeeds in drawing to their capabilities the attention of those who are competent to develop their resources, it will have performed good service.—*Nature.*

JOURNAL OF THE ROYAL UNITED SERVICE INSTITUTION.—London: W. Mitchell & Co. For sale by Van Nostrand.

The present number (65) of this journal presents among other articles relating to army or navy affairs, an illustrated article "On the Turbine Propeller"—On Ocean Currents—On Defensive Submarine Warfare, and a Description of a Chinese Torpedo.

THE MANUFACTURE OF STEEL. By M. L. GRUNER; translated by LENOX SMITH, A. M. New York: D. Van Nostrand.

The well-known ability of the author in the line of metallurgical research will insure for this new translation an eager reception from American readers. No metallurgical industry interests the world so largely as that which has for its object the production of iron and steel, and there is no branch of manufacture which involves so many perplexing problems.

The table of contents herewith presented will afford our readers the best possible means of judging of the value of the work.

CONTENTS.—Translator's Preface; Nature of Steel; Hardness and Tenacity of Steel dependent on Carbon; Various methods for the manufacture of Steel; I. Fining Pig Iron not melted, producing malleable Cast Iron of a steely nature; II. Fining molten Pig Iron, giving solid steely products; III. Fining molten Pig Iron, giving molten steely products; Bessemer Process in France; Bessemre

Process in England; New Rolling Appliances used in England; Bessemer Steel in Sweden; Bessemer Steel in Austria; Bessemer Process in Belgium, Prussia, Russia, Italy, etc.; New Mode of assay in Bessemer fining used in Germany; Defects of the Bessemer Process—means of remedying them; Berard's Process; Fining by reaction; Experiments in manufacturing Cast Steel in the Reverberatory Furnace; The Martin Process at Sireuil; Manufacture of refined Pig Iron; IV. Manufacture of Steel by Cementation; Ordinary Cementation; Theory of Cementation; Cementation and simultaneous fusion in Crucibles; Cementation and fusion in a Cupola Furnace (Parry Process); Determination of the Carbon in Steels by the Eggertz Method; Determination of Sulphur by the Eggertz Method; Additional Note; Explanation of Plates; Appendix—The Bessemer Process in the United States.

Fine folding plates illustrate the text.

By no means the least interesting or important portion of the work is the Translator's Appendix, describing the Bessemer Process of the United States.

THEORY OF HEAT. By J. CLERK-MAXWELL, M. A. Professor of Experimental Physics in the University of Cambridge. London: Longmans & Co.

Here we have another of Messrs. Longmans' useful series of Text-books of Science. The theory of heat is a subject on which a great deal of misconception prevails, and this clear and concise statement of what is accepted, and why it is so accepted, is a valuable addition to our opportunities of acquiring a knowledge of the matter. The aim of the book, according to the author, is to exhibit the scientific connection of the various steps by which our knowledge of the phenomena of heat has been extended. The first of these steps is of course the thermometer, the second the calorimeter, by which the quantities of heat are measured. These instruments give us the means of founding a science of heat, and when their records are thoroughly understood we can investigate the relations between the thermal and mechanical properties of various substances and understand the laws of thermo-dynamics. Professor Clerk-Maxwell takes the student step by step through the various branches of the theory and cognate subjects, commencing with the "meaning of the word temperature," and ending with a chapter on the molecular theory of the constitution of bodies. In a work of this kind it is of course almost absolutely necessary to employ some mathematical formulæ, but the author has apparently taken care that they are not beyond the grasp of the average student who is earnest in a desire to acquire a knowledge of his subject. The book is illustrated with wood-cuts and explanatory diagrams, and worthily fills its place in the series.

RUDIMENTARY MAGNETISM: A Concise Exposition of the General Principles of Magnetical Science and the Purposes to which it has been Applied. By Sir S. HARRIS, F. R. S. Second edition: Revised and enlarged by Dr. H. M. Noad, F.R.S. With 165 illustrations. (Lockwood and Co., 1872.)

Snow Harris was one of those heaven-born expounders of elementary science whose works will long survive themselves and excel in some new form when their experiments and theories have become obsolete. Nothing of the kind has been written which can be compared with the three little treatises in his own department of science, which Sir William contributed to "Weale's Series." We therefore applaud Dr. Noad's discretion when he tells us that "No attempt has been made to alter in any degree the general character and style of the work." Of course the progress of science has rendered some additions here and there necessary; and Dr. Noad has distinguished his new matter by the use of brackets. Such additions relate chiefly to Faraday's latest researches in magnetism, and to the more recent investigations of the Astronomer Royal and others, respecting the deviations of the compass in iron ships. The editor has also added a chapter, giving an account of the progress of investigations in terrestrial magnetism, during the last twenty years. These investigations have a singular interest attached to their cosmical relations, and the deviations of the compass on board ship have great practical value. There is a good index, and this volume of 412 pages may be considered the best possible manual on the subject of magnetism.

NOTE BOOK ON PRACTICAL SOLID OR DESCRIPTIVE GEOMETRY. By J. H. EDGAR, M. A., and G. S. PRITCHARD. (London and New York: Macmillan & Co., 1871.)

The editors—practical teachers—tell us that they hope this will prove useful as a class-book, and as a means of self-instruction to the various and constantly increasing classes of students for whom it is designed. It was originally intended as an aid in teaching the mechanical drawing class at the Royal School of Mines, from Professor Bradley's "Elements of Practical Geometry." Having been associated with him in his duties at King's College, London, and the Royal Military Academy learning the value of his treatise, the authors have produced this book for those to whom the cost of his work rendered it inaccessible. There is a large number of problems, with help for solutions.

ELEMENTARY STATICS. By J. HAMBLIN SMITH, M.A. (Cambridge: Rivingtons, 1871.)

A little work intended to explain statical principles required for the Previous Examination and the Second Examination for Ordinary Degrees, at Cambridge, is now formed also to meet the wants of pupils in schools who are preparing for the Local Examinations. It has the same merits in clear and logical statement, and numerous examples selected from papers set in University Examinations, that distinguish the rest of Rivingtons' admirable "Mathematical Series."

MISCELLANEOUS.

ICE-MAKING IN THE TROPICS.—The most marked example of the influence of radiation of heat on temperature is its influence on the production of artificial ice by the natives of India.

The fields in which the ice is made are low, flat, and open; and the ice is produced in large quantities when the temperature of the air is 16 or 20 deg. Fahr. above the freezing point. The plan followed is an interesting example of accurate observation applied to practical purposes by a people ignorant of science. The same process has been employed from time immemorial in India with scientific accuracy; and while the theory was explained by Dr. Wells, the practical application was not so well understood; and this first led me to investigate the subject in India.

At the town of Hooghly, near Calcutta, in fields freely exposed to the sky, and formed of a black loam soil upon a substratum of sand, the natives commence their preparations by marking out a rectangular piece of ground 120 ft. long by 20 broad, in an easterly and westerly direction, from which the soil is removed to the depth of 2 ft. This excavation is smoothed, and is allowed to remain exposed to the sun to dry, when rice-straw in small sheaves is laid in an oblique direction in the hollow, with loose straw upon the top, to the depth of $1\frac{1}{2}$ ft., leaving its surface $\frac{1}{2}$ ft. below that of the ground. Numerous beds of this kind are formed, with narrow pathways between them, in which large earthen water-jars are sunk in the ground to fill the shallow unglazed earthen vessels in which it is to be frozen. These dishes are 9 in. in diameter at the top, diminishing to 4.3 in. at the bottom, 1.3 deep, and .3 in. in thickness; and are so porous as to become moist throughout when water is put into them.

During the day, the loose straw in the beds above the sheaves is occasionally turned up, so that the whole may be kept dry, and the water-jars are filled with soft pure water. Towards evening, the shallow earthen dishes are arranged in rows upon the straw, and by means of a small earthen pot, tied to the extremity of a long bamboo rod, each is filled about a third with water. In all cases, more water is put into the dishes nearest the western end of the beds, as the sun first falls on that part, and the ice is thus more easily removed, from its solution being quicker.

In the cold season, when the temperature of the air at the ice-fields is under 50 deg. Fahr., and there are gentle airs from the northern and western direction, ice forms in the course of the night in each of the shallow dishes. Persons are stationed to observe when a small film appears upon the water in the dishes, upon which the contents of several are mixed together, and thrown over the other dishes. This operation increases the congealing process; as a state of calmness has been discovered by the natives to diminish the quantity of ice produced. When the sky is quite clear, with gentle steady airs from the N.N.W., which proceed from the hills, of considerable elevation near Bheerboom, about 100 miles from Hooghly, the freezing commences before or about midnight, and continues to advance until morning. The thickest ice is thus formed. I have seen it $\frac{7}{10}$ in. in thickness. In a favorable night, upwards of 10 cwt. of ice is obtained from one bed.

When the wind attains a southerly or easterly direction, no ice is formed, from its not being sufficiently dry; not even though the temperature of the air be lower than when the wind is more from a northern or western point. The N.N.W. is the most favorable direction of wind for making ice, and this diminishes in power as it approaches the due north or west. In the latter case more latitude is allowed than from the N.N.W. to the north. So great is the influence of the direction of wind on the ice, that when it changes in the course of a night from the N.N.W. to a less favorable direction, the change not only prevents the formation of more ice, but dissolves what may have been formed. On such occasions a mist is seen hovering over the ice-beds, from the moisture over them, and the quantity condensed by the cold wind.

A CONTINUED range or curb of timber was discovered in pulling down a part of the keep of Tunbridge Castle, in Kent, which was built about 750 years ago. This curb had been built into the middle of the thickness of the wall, and was no doubt intended to prevent the settlements likely to happen in such heavy piles of building, and therefore is an interesting fact in the history of constructive architecture, as well as an instance of the durability of timber. In digging for the foundation of the present house at Ditton Park, near Windsor, the timbers of a drawbridge were discovered about 10 ft. below the surface of the ground; these timbers were sound, but had become black. Hakewell says that Sir John De Molines obtained liberty to fortify the Manor House at Ditton, in 1396; and it is most probable the drawbridge was erected soon after that time; and accordingly the timber had been there about 400 years.

THE question of building iron barges for canal transit is beginning to attract considerable attention at Buffalo and other cities immediately interested in canal business. The experiment of iron boats was tried many years ago, and only failed because of the then greater cost of iron over wood, and the want of facilities which now exist for repairing the iron hulls. These objections no longer exist, and we understand the relative advantages of wood and iron are to be again tested by the construction of iron barges to run in competition with boats already engaged in the canal service. The advantages claimed for iron boats are that they are lighter, and, owing to the thinness of their sides, have a greater stowage capacity for freights than the most capacious wooden boats that can pass the locks. Should these claims be substantiated by actual trial, and we have no doubt they will, it is not improbable that iron will supersede wood upon canals, as it is now doing in river, coastwise, and ocean navigation.

THE EAST RIVER BRIDGE.—The excavation under the caisson on the New York side of the river has progressed of late with much greater rapidity than was promised at the beginning of the work. The excavation of sand is nearly completed, and the operations upon the rock foundation about to commence. The uneven surface presented by the gneiss formation upon which the caisson is to rest requires yet some difficult engineering labor, but which the skill of the engineers is, doubtless, competent to overcome.

THE largest iron casting ever attempted has been successfully achieved at the Elswick Ordnance Works, Newcastle-on-Tyne, under the direction of Sir William Armstrong and Capt. Noble. It was a huge anvil block, weighing 125 tons, to be used with a 20-ton double action forge hammer, for performing the necessary forging for the 35-ton Armstrong gun.

VAN NOSTRAND'S
ECLECTIC
ENGINEERING MAGAZINE.

NO. XLI.—MAY, 1872.—VOL. VI.

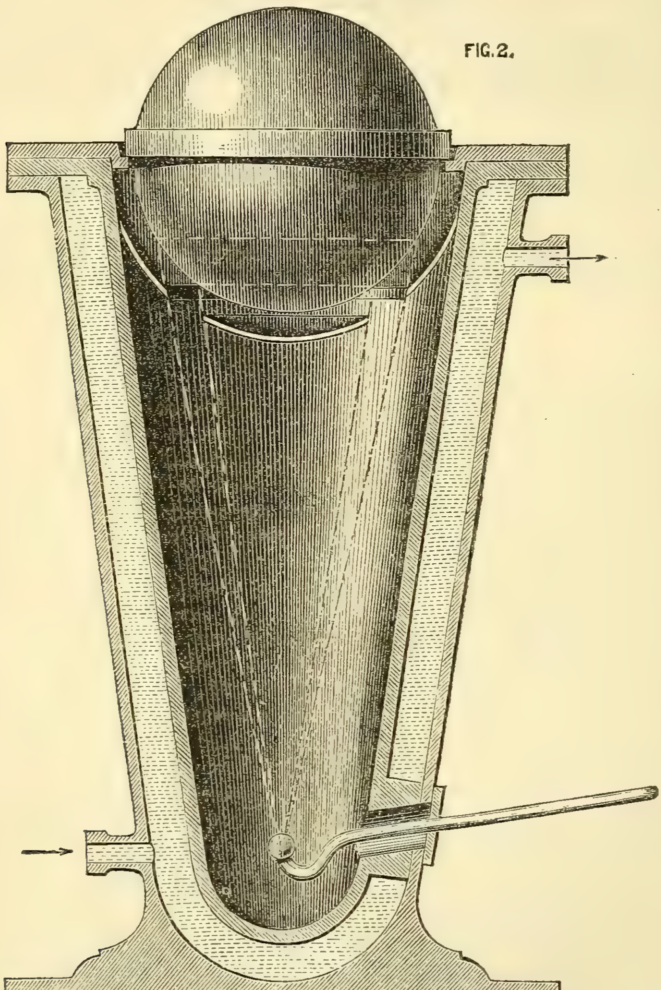
RADIANT HEAT TRANSMITTED BY INCANDESCENT SPHERICAL BODIES.

By Captain JOHN ERICSSON.

From "Engineering."

The question whether equal areas at different points of the solar surface transmit equal energy towards the earth has not been satisfactorily answered. We have seen in the previous articles relating to radiant heat that the author of "Mécanique Céleste," finding by observation that equal areas do not transmit equal energies (the central regions transmitting, in opposition to his reasoning, much greater intensity than those near the border), explains the matter by showing that the solar atmosphere retards the passage of the rays, causing a great diminution of the energy of the radiant heat projected towards the earth. It but seldom happens that questions of a cosmical nature admit of being decided by actual experiment, the present being one of the rare instances in which practical tests may be resorted to. Evidently if the great diminution of energy towards the border demonstrated in the work adverted to is caused solely by the retardation offered during the passage of the rays through the atmosphere surrounding the photosphere, the receding surface of an incandescent spherical body of any size whatever, *not* surrounded by a retarding medium, will transmit its radiant heat undiminished. The illustration on the next page shows a mechanical device by means of which it has been clearly demonstrated that the absence of a retarding medium round an incandescent sphere does not affect the diminution of energy resulting from the obliquity of the heat rays projected by the receding surface. Fig. 2 represents a vertical section of a conical vessel surrounded by a water jacket, and in other respects similarly constructed to the one delineated in the preceding article on radiant heat emitted by inclined discs. The top flange, however, of the vessel here presented is provided with a groove, the bottom of which supports a solid sphere of cast iron, in the manner shown by the illustration. Below the sphere are inserted two semispherical screens of different diameter, an annular opening being thereby formed between the same. Supposing the sphere to be heated before being placed in the position shown, it will be perceived that the thermometer at the bottom of the conical vessel will only receive the radiant heat which emanates from the zone contained within the dotted horizontal lines shown in the drawing. The heat rays from this zone, converging in the centre of the bulb, are indicated by dotted radial lines. It is evident that by changing the dimensions of the screens, zones covering *equal areas*, but occupying *different* positions, may be made to radiate towards the thermometer, and that, by this means, the radiant power of any portion of the sphere may be accurately ascertained. We are accordingly enabled to test the correctness of the assertion, that "but for the intervention of the sun's atmosphere, the receding solar surface would, owing to the increased number of rays within a given section, produce increased intensity. It may be urged against our device that atmospheric air intervenes between the incandescent sphere and the recording thermometer, but a moment's consideration will show that the consequent retardation is practically inappreciable. The retardation of the sun's rays in passing through the depth of 28,800 ft. of atmospheric air of maximum density, on the ecliptic, it has been demonstrated in pre-

FIG. 2.



vious articles, amounts to 0.207, while solar intensity at the boundary of the atmosphere is somewhat under 85 deg.; hence the loss of radiant heat will scarcely reach 17.5 deg. Fahr., notwithstanding the great depth of atmospheric air penetrated. The radiant heat of our experimental apparatus being trasmitted through a depth of less than 2 ft., we may, without material error, assume that no retarding medium surrounds the experimental incandescent sphere. The principal features of our apparatus having thus been explained, and the method of solving the problem under consideration pointed out, we may now proceed to consider the result

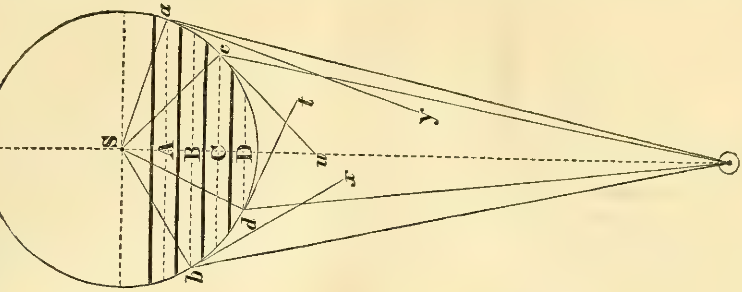


FIG. 7.

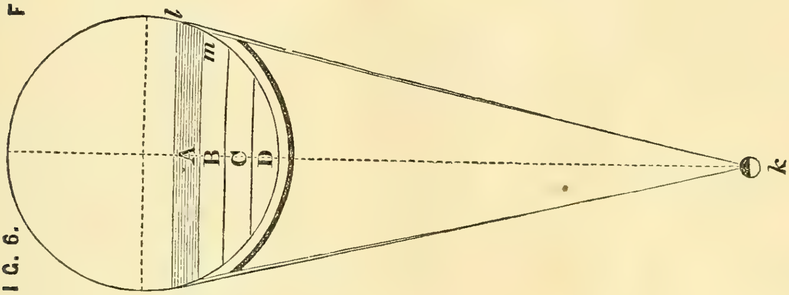


FIG. 6.

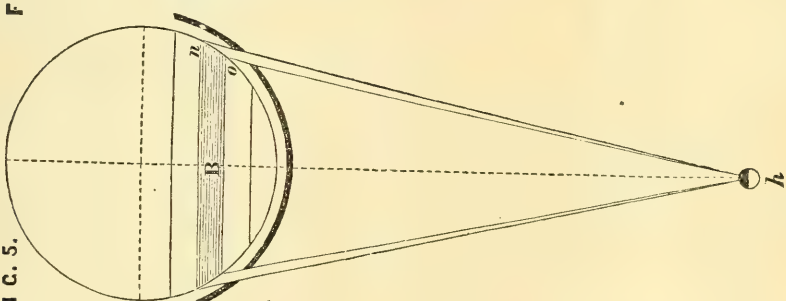


FIG. 5.

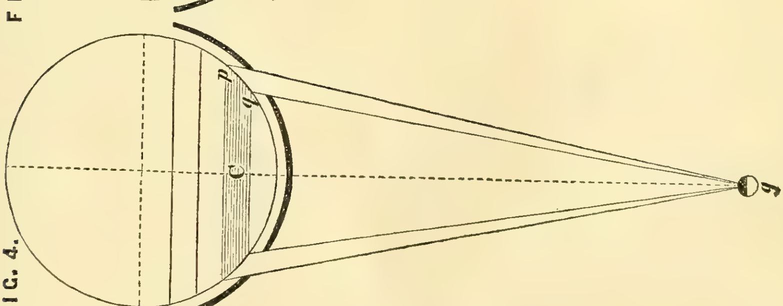


FIG. 4.

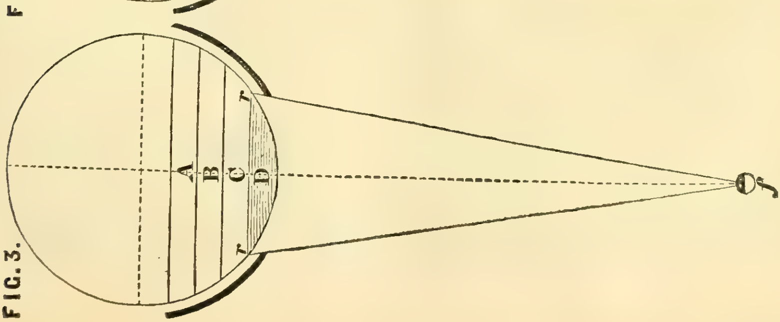


FIG. 3.

of the experiments which have been instituted. In order to facilitate comparison, the lower part of the sphere visible from the centre of the bulb of the recording thermometer (see Fig. 6), has been divided into four zones, A, B, C, and D, containing equal areas. It will be evident on inspecting the arrangement represented in Fig. 2, that no part of the surface of the sphere excepting that contained within the dotted parallel lines, is capable of radiating towards the thermometer, all the rest being shut out by the semispherical screens. Obviously the latter can be so proportioned that the radiant heat from any part of the lower half of the sphere may be projected towards the bulb. Figs. 3, 4, 5, and 6 show the arrangement of screens adopted in our experiments, by means of which the radiant power of each of the zones has been ascertained. The dimensions of the several screens have been determined by drawing radial lines from the centre of the bulb of the thermometer to the points where the termination of the zones intersect the circumference of the sphere. The subject will be most readily understood by refering to Fig. 4, which exhibits zone C. The screens being made to terminate in the radial lines, *p*, *g*, and *q*, *g*, it will be seen that an annular opening, *p q*, is formed, permitting all heat rays to pass which are projected from the zone C, in the direction of the bulb of the thermometer. A similar arrangement permits the radiant heat from zone B, in Fig. 5, to act on the thermometer. Referring to Fig 3, it will be found that only one screen, perforated in the centre, is required to shut out the radiant heat from the three upper zones, C, B, and A; while in Fig. 6 the radiation from the three lower zones, D, C, and B, is shut out by a single central semispherical screen, the circumference of which is defined by the radial lines, *m*, *k*. It is proper to observe that, although the several screens are represented by single lines, in the diagram, they are in reality composed of double plates, a fire-proof non-conducting substance being inserted between the two, the object of which is self-evident.

Bearing in mind the demonstration contained in the previous article relating to the diminution of energy of heat rays projected at an acute angle to the radiant surface, it will be perceived, on mere inspection, that the upper zones represented in our diagram, though containing an equal area with the lower zones, cannot posssibly transmit the same temperature as the latter. The advocates of the views expressed in "Méchanique Céleste" will be surprised to learn that, notwitstanding the absence of an intervening retarding medium, so great is the difference of energy communicated, that while the zone D, of the experimental incandescent sphere, transmits a temperature of 42.5 deg. to the thermometer, the zone A transmits only 4.7 deg. The latter zone being further from the thermometer than the former, a correction is, however, necessary on account of the increased dispersion of the heat rays before reaching the bulb. This correction being made, the true ratio of temperature transmitted by the zones D and A, will be 42.50 deg.: 6.19 deg. Consequently, the heat rays projected from the lower zone of the incandescent sphere towards the bulb of the thermometer, transmit nearly seven times higher temperature than the rays from the upper zone. The amount of radiant surface being alike in each zone, while the temperature of the sphere is uniform throughout, it will be admitted that our practical test has clearly demonstrated the feebleness of the rays of heat projected from the border of an incandescent sphere towards a given point. It is hardly necessary to add that each zone has called for a separate experiment, rendering re-heating of the sphere indispensable for each. The same expedient has, therefore, been resorted to in order to insure an equal degree of temperature during each experiment, as in the case of the incandescent inclined disc, discussed in the previous article. Of course, it has been found impracticable to impart an equal temperature to the sphere for each operation; but this difficulty has been satisfactorily overcome by establishing a mean, as in the case referred to. Besides, the result may be checked by computing the degree of temperature capable of being transmitted to the recording thermometer by each zone, in accordance with the relation which the intensities bear to the angles formed by the radiating surface and the heat rays projected towards the centre of the bulb. Before giving an account of our experiments, let us, then, demonstrate, theoretically, what temperature each zone ought to communicate to the thermometer, in conformity with the ascertained fact, that the intensity of the radiant heat transmitted by an incandescent disc, is directly proportional to the sines of the angles formed by the projected heat rays and the radiating surface. In order to simplify the demonstration, the several zones have been divided into halves, by a dotted line, see Fig. 7; radial lines being drawn to the thermometer at Z, from the points of intersection of the dotted lines and the circumference of the sphere. Tangential lines, *d t*, *c u*, *b x*, and *a y*, have also been drawn from the points of intersection referred to. It will be evident on considering the properties of spherical zones, that the radial lines, *d* Z, *c* Z, *b* Z, and *a* Z, represent the mean direction of the heat rays projected by each zone respectively, towards Z. Hence the sines of the angles, *t d* Z, *u c* Z, *x b* Z, and *y a* Z, will determine the amount of radiant heat transmitted towards Z, by each of the zones, D, C, B, and A. Calculation shows that if the sine of the angle *t d* Z, be represented by unity, the sines of the other angles, in the order presented, will be 0.671, 0.384, and 0.121, while the experiments which have been made show that the zone D transmits a temperature of 42.50 deg. to the recording thermometer. Consequently, the zones, C, B, and A, ought to transmit respectively 28.50 deg., 16.31 deg., and 5.16 deg. to the thermometer at Z. The accompanying Table shows to what extent the

1. Zone.	2. Mean angle of projection.	3. Comparative sine.	4. Observed temperature.	5. Corrected temperature.	6. Computed temperature.
	deg. min.		deg.	deg.	deg.
D....	58 0	1.000	42.5	42 50	42.50
C.....	34 40	0.671	24 2	27.49	28.50
B.....	19 0	0.384	10.1	12 82	16 31
A.....	5 55	0.121	4.7	6.19	5.16

actual temperatures transmitted by the incandescent sphere differ from the stated computed temperatures. It should be observed that no direct comparison can be based upon the temperatures entered in the fourth column, since the heat rays projected by the several zones are subjected to different degrees of dispersion, owing to the unequal distance from the thermometer. Due allowance being made for the dispersion of the rays, in conformity with the elements furnished in Fig. 7, the consequent augmentation of temperature has been added, and the corrected values entered in the fifth column of the Table. The computed temperatures will be found in the sixth column. It will be supposed at first sight that the figures entered in the Table indicate a serious discrepancy between the observed and the computed temperature. That such is not the case will be found on referring to Fig. 8, in which the ordinates

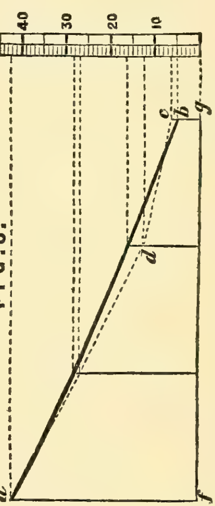


FIG. 8.

of the regular curve, *a b*, represent the computed temperatures, while the ordinates of the irregular curve, *a d c*, represent the observed temperatures. Obviously, the computed and the observed energies transmitted by the radiation of the incandescent sphere, is truly represented by the superficies contained between the base, *f g*, and the curves, *a b* and *a d c*, respectively, the ratio being 1.000 : 0.945. Considering the insignifiance of this discrepancy, in connection with the difficulty of bringing the heated sphere to an equal degree of incandescence during each experiment, it will be admitted that the instituted test has proved conclusive, and that the inaccuracy of the theory promulgated in "Méchanique Céleste" regarding the radiant energy transmitted by the sun, has been fully demonstrated.

ON THE TURBINE PROPELLER.

By ANDREW MURRAY, Esq., C.B., etc.

From "The Journal of the Royal United Service Institution."

It is hoped that the importance of the subject, and the special interest it has for naval men, will be considered such as to form a sufficient excuse for bringing the system of hydraulic propulsion again before this Institution, though little has been done in respect to it since it was last discussed here. At that time the Waterwitch, built for the Admiralty on the recommendation of the late Controller, at the instigation of Vice-Admiral George Elliot, propelled on the principle of recoil from an effluent stream of water driven out by a centrifugul pump revolving horizontally in the vessel, had just been completed, and tried, and her performances were given in full.

In the great change from the paddle-wheel to the screw, the Admiralty led the way with the Rattler, and the block ships (mainly at the instigation of the Right Honorable H. T. L. Corry), appreciating its special applicability to men-of-war in comparison with the paddle-wheel, several years before it was taken up by the mercantile service; and, as they have now again led the way with the Waterwitch, in consequence of a claim having been put forward for superiority on the part of the turbine propeller over the screw, it is to be hoped that they will proceed with equal boldness in testing it to the full extent, and not allow the expense to which they have already gone to remain fruitless. It has been admitted that the results were more favorable than had been anticipated by the professional Officers of the Controller's Department in London, when the experiments were first sanctioned (though quite in accordance with those promised in the Report that led to this sanction being given), and this being so, there appears to be no just grounds for not continuing and extending the trials.

The principle on which the turbine propeller acts may be briefly explained by stating that as a gun recoils on the explosion taking place, or as the progress of a rocket is kept up by the recoil arising from the efflux of the gases generated by the ignition of the composition with which the rocket is filled, so the progress of the vessel is kept up by the recoil arising from the efflux of a stream of water in a sternward direction, kept up by the action of a centrifugal pump or turbine, driven by a steam-engine, drawing water from the sea and discharging it sternwards in a continuous stream through a bent pipe or nozzle at a high velocity. The principle may also be illustrated by supposing a cylinder closed at the ends and filled with an elastic gas or vapor in a highly compressed state, and therefore at a great pressure, in which case the pressure would be equal in all directions on the surface of the cylinder, and there would be no action beyond a bursting tendency; but if one end were to be suddenly removed the pressure on the opposite end would be no longer balanced, and the pressure would produce motion by its action, if it should be sufficient in amount to overcome the weight or inertia, or resistance of the cylinder or vessel.

The object of the present paper is to endeavor to awaken interest in the turbine again, and to enlist additional advocates amongst naval men for further experiments. The success of the Waterwitch, as a first attempt in the Government service, was certainly as great as was that of the Rattler, and this success ought to outweigh the misgivings and counterbalance the adverse views expressed by men of science, and which it is believed have tended much to retard the progress of the system up to this time. When the determination of the Admiralty, in 1864, to sanction the construction of the Waterwitch, under the patent of Mr. Ruthven, became known, it gave occasion to several mathematicians to investigate the question afresh, and bring to bear upon it some new views in fluid dynamics. In more than one instance the utter failure of the Waterwitch was predicted in the most confident manner from these investigations, but the degree of success she attained may be taken as evidence of the difficulty of any investigation of this kind, and that too much reliance had been placed by those writers on the formulæ adopted by them. In a recent discussion at the Institution of Civil Engineers, on the best form of the Archimedean screw for raising water, and on centrifugal pumps, the Astronomer Royal stated that the motions of fluid particles amongst themselves were, in his opinion, too complicated to be reduced to any definite formulæ sufficiently simple to allow practical deductions to be drawn from them. With such an authority to quote, further reasoning as regards those calculations that start from theoretical grounds only, may be dispensed with; but there are other mathematical investigations that claim to be founded on practical facts, and it may be well briefly to consider these. They must, of necessity, involve a calculation of the amount of loss resulting from the friction of the particles of water amongst themselves and against the sides of the pump, especially if a centrifugal pump be used, and against the sides of the pipes or passages to and from the pump. In centrifugal pumps of 40 or 50 horse-power, used for raising water, which, though considered of a large size for such a purpose, might almost be looked upon as models in comparison with those which must be used in the propulsion of ships of any size, the results realized have been found by actual test to vary from about 50 to 80 per cent. of the full power expended, the difference arising from mere differences in the form of the blades and other details of construction. With this fact patent to us, how can any calculation of the speed to be expected from a ship be depended on, when that speed can be materially affected by the efficiency, or otherwise, of such minute points? In attempting a comparison, however, between the paddle-wheel, or screw, and the turbine, to lay before this Institution, on general grounds, without entering into any minute points of science or engineering, it will be necessary to recall to mind some of the facts, and the deductions drawn from them respecting the former. In the common paddle-wheel a considerable portion of power is lost from the obliquity of the action of the paddle-board or float in its revolution as it enters and leaves the water, the reaction of the water not being at all points in the line of direction in which the effect is desired to be produced upon the vessel, and other portions of power are lost from setting a portion of water in motion in a sternward direction, and from the float lifting or raising, and throwing backwards a portion of water as it rises.

In the use of the screw, likewise, a portion of water is set in motion in a sternward direction, and power is lost in proportion in obtaining the reaction or the push required for the propulsion of the ship. In a very able paper on the action of the screw propeller, by Mr. Froude, he illustrates this by supposing a separate ideal current to be in existence where the screw works, flowing in the direction of the ship's motion, without its acting on the ship, and that the propulsion is obtained by each blade of the screw in its rotation meeting so much of this current and acting upon it with exactly that force that is sufficient to stop it, and thus, by raction, obtaining back from it the exact force exerted. He considers that this would be a perfect system of screw propulsion, no power being wasted in giving motion to any particles of water, but the whole made useful in propelling the ship, except that absorbed in overcoming the friction of the surface of the screw.

That the amount of power so lost by the paddle-wheel is great is admitted by all writers upon it, and it is also admitted by the writer on the screw, before quoted, that a great deal of force is exerted by it to no purpose.*

It is difficult, however, to determine the amount of this loss separate from the power lost by the engine itself in the friction and the working of its own various parts, and this is not attempted in that paper. Aristides Mornay, in the last edition of "Tredgold on the Steam Engine," estimated it for the ordinary paddle-wheel at above 40 per cent. for the oblique action of the floats on the water, without taking into account the loss from putting the water in motion. The loss of power from the screw has been variously estimated, but from the early experiments with the dynamometer in the Rattler, and from other data, it may be inferred that the loss does not vary much from that of the paddle-wheel; but in both these cases the losses named are little more than mere estimates.

* FROUDE, "Transactions of Naval Architects' Institution," 1867, page 77.

The amount of loss arising from the action of the steam-engine and the propeller combined, compared with the gross power developed in the cylinders of the engine, as shown by the indicator diagrams, is more within our reach. If this total loss can be ascertained, when different propellers are used, good grounds are obtained for judging of their relative efficiency, because it may very well be inferred, or rather proved, that in all well made steam-engines of the same horse-power, and of similar arrangements in their parts, the amount lost will not vary much, as all the parts involving the great proportion of the loss by friction must of necessity be nearly alike. If the average total pressure on the surface of the pistons of a pair of direct-acting paddle-wheel engines be obtained from the indicator diagrams, and the total number of pounds, or tons, acting on the end of the crank be found from this, the equivalent weight acting at the centre of pressure of the paddle-board that would balance that amount, can be found as a mere question of leverage.

The actual weight, or force, exerted at the centre of pressure of the paddle-float, instead of the weight so found to balance the total pressure on the pistons, has been made the subject of direct experiment, by attaching a vessel by a hawser to a dynamometer in the form of a bent steel yard fixed on shore, and setting the engines to work, and though the motion of a vessel through the water alters the circumstances under which the paddle-wheel or the screw acts, yet the result is interesting and useful, not only as showing the amount of power lost, but as giving a means of comparison of the effect from different forms of paddle-wheels, or screws, or propellers, of any kind. If the same propellers be fitted to similar ships with different kinds of engines, it would show the difference in the effective powers of their engines. It also illustrates the little effect produced by a steamer attached to a vessel on shore to drag her off, and that the mere push of a vessel without way, or with but little way, on her, would be comparatively useless as a ram to run down an enemy, a point that seems to have been rather too much lost sight of in some of the discussions on this subject. As an example, a small paddle-wheel vessel, with engines of 150-horse power nominal, the cylinders being 48 in. diameter, and the length of stroke 3 ft. 9 in., was tried in this way. The average pressure on the pistons was found by the indicator diagrams to be 18.16 lbs. per. sq. in., this gave a total pressure of 30 tons on the two pistons acting on the crank at a leverage of 1 ft. $7\frac{1}{2}$ in., half the stroke; the paddle-wheel was 13 ft. diameter to the centre of pressure of the float, and the weight at the radius of 6 ft. 6 in. to balance 30 tons at 1 ft. $7\frac{1}{2}$ in. would be 4.615 tons, but instead of this the actual pull, as shown by the steel-yard on shore, was only 3.078 tons, a loss of more than one-third in direct pressure, while the loss of effect in horse-power by taking into account the speed or travel of the piston and the travel of the centre of effort of the paddle-float, was from 369.6 indicated horse-power in the cylinders to 204.4 indicated horse-power on the paddle-float, or in the ratio of 100 to 55.3. This gives a dead pressure or pull of about 2 tons only for every 100 indicated horse-power when the vessel has no way on her, and thus proves the loss incurred when using the paddle-wheel as a propeller, other vessels when tried in the same way giving similar results.

The total loss from the action of the engine and the screw combined has been estimated at about one-third of the gross indicated horse-power in the cylinders.

From the circumstance that no loss from putting water in motion in a sternward direction in the manner before referred to, occurs with the turbine, it has been argued that it must, therefore, be a more efficient propeller, and that it has no slip. The meaning intended to be conveyed by this latter expression is obvious, but it may be doubted whether it is correct. With the turbine it would seem that a loss of power must take place in imparting a forward motion, equal to the speed of the vessel, to the water which is being constantly taken up from the sea in a state of rest, and carried along with the ship, before it is thrown out at the nozzles, so that this may to some extent be equivalent to the loss incurred by the paddle-wheel or screw in putting water in motion in a sternward direction. Again, the speed of the ship is not necessarily the same as that of the water issuing from the mouth of the nozzle, and if this difference were called the slip of the turbine, it might be more in accordance with the term as applied in the other case, though it does not prove that any loss of power arises from any such difference.

The question, then, of the relative efficiency of these different propellers seems to narrow itself very much into the question of the efficiency of a centrifugal pump or the percentage of effect to be obtained from it. With this, as before stated, the loss has been tested by actual experiment, and has varied from 20 up to 50 per cent., so that if the full value of the reaction be obtained, there seem to be grounds for believing that the turbine will prove as efficient as the others. It has been questioned, however, whether the effect of a centrifugal pump in raising water affords just grounds for estimating its efficiency as a propeller. In the former the object desired is the raising or delivering the greatest quantity of water possible, while with the propeller the objects are area and pressure; but as the quantity delivered will be in accordance with the area of the discharging orifice and the velocity of the effluent water, and as velocity and height of discharge can only be got by pressure, it would seem that the objects desired are so far identical, and that the pump which showed the greatest efficiency in the one case would also show the greatest efficiency in the other.

To revert to the facts of the case between the Waterwitch and the sister vessels the Viper and the Vixen, the final results which were obtained in August, 1867, after the first preliminary experimental trials, were a speed of 9.237 knots, with 777 indicated horse-power, for the Waterwitch, against 9.475 knots, with 652 indicated horse-power, for the Viper, and 9.060 knots, with 658 indicated horse-power, for the Vixen. (Full details of the vessels and trials are given in an appendix.) Such a performance for so early an attempt may certainly be claimed as a great triumph for a system so completely different from the other modes of propulsion in use. It places the turbine almost on a par with the screw, and it is to be regretted that the patentees were not satisfied with this, but allowed their partiality and their enthusiasm in favor of their invention to carry them away so far that they claimed 20 to 30 per cent. advantage for the turbine, and affirmed that the official returns understated the horse-power exerted in the Viper and the Vixen, and also that the engines of the Waterwitch did not give out the power that was due from them and from the boiler. These claims and statements have undoubtedly tended much to retard the progress of the system, parties who were favorable to it being unable to endorse them, and inquirers, in consequence, became puzzled to know how much to believe, and hung back. It is not proposed now to answer these points in detail, but it may be generally stated that they are based on scientific considerations. It is argued by the patentees that the results and the coefficients of performance derived from the first trials of the Viper and Vixen at the Maplin Sands, are irreconcilable with those derived from the subsequent trials of the same vessels at Stokes Bay, and they therefore wish to discredit the whole results. The discrepancy referred to, however, is amply accounted for from the fact that in these vessels which are built with 2 after-bodies, 2 stern-posts, and 2 rudders, with a screw in each after-body, the screws used in the first trials at the Maplin Sands were inefficient. There is a space between the two after-bodies which may be looked upon as a covered passage way, the roof of which slopes down to meet the water and then onwards to the bottom of the ship, and the water in this space is necessarily in a very disturbed state. The two screws with which the vessels were tried at the Maplin Sands turned inwards towards this disturbed water, there being little or no previous experience on this form of a vessel's body ; but new screws were made for the trials at Stokes Bay, and these were arranged to turn outwards, and the effect was so different that a discrepancy between the results derived from these two sets of trials cannot be looked upon as a matter of surprise, as if all the circumstances had been alike. The differences in the coefficients derived from the one set of trials of these vessels at Stokes Bay are not greater than are found in ordinary cases. In the Philomel, whose performances are quoted and argued upon by the patentees of the turbine as reliable, the coefficient varies from 302 to 316, a difference of 14, while in the Viper it varies from 426 to 439, a difference of 13, for the full power trials. The Vixen was tried once only. Calculations were also made from the number of cubic feet of steam calculated to have been used in the cylinders, taking the indicator diagrams as the foundation for this calculation, and it was argued from these that the engines were not developing a proper amount of power; but the researches of Professor Tyndall, Professor Rankine, and others, have shown that the absorption of heat and the condensation of steam which are found in all engines, and wherever motion takes place, are such, that a calculation of this kind does not rest on a sound foundation.

Professor Main investigated this question in the Bee, at Portsmouth, many years ago, and naval officers do not require anything more than the mention of his name, and that of Mr. Brown, to feel satisfied that the experiment would be conducted with the greatest care, and the results be scrutinized with intelligence and industry, and he failed entirely, as stated in his work on the marine engine, in bringing the amount of steam, as shown by the indicator in the cylinders, into accordance with the amount of water known to be evaporated by the boiler. This experiment was made by him long before the researches of Professor Rankine, who has shown why they cannot be in accordance. Those calculations, therefore, afford no grounds for the assumption that less net effective power was given out by the engines of the Waterwitch to the turbine, than is given out by other engines to the propellers which they may have to drive.

The indicated horse-power shown by the "Philomel" class, in comparison with that shown by the Viper and Vixen, all being of the same nominal horse-power, has been relied on as a proof that the power exerted by the engines of the latter was understated in the official returns, but the Philomel is of later construction, and her boilers are different, and though the diameters of the cylinders and the length of stroke of the engines are the same, yet the fact that these boilers are loaded to 30 lbs. pressure, instead of 22 lbs., and that her engines made 118 and 119 strokes against 108 and 109, it is evident that the indicated horse-power may well be increased, and no argument can, therefore, be founded on this to prove that the amount of power realized by her engine was not in reality greater than that realized by those of the Viper and Vixen.

A further attempt to prove the same point was based on the relative midship sections and speeds of the Philomel and of the Viper and Vixen, that the latter vessels attained the speed they did with less power relatively than the Philomel, for the speed that she attained, and that this must be wrong, because they are fuller and carry armor, while the Philomel is unarmored, is of less beam, and is longer. The first argument referred to, as used by the patentees of the turbine, was based on the coefficient of effect derived from the midship section, which they state is received as a distinct proof of the value of a propeller, and that any departure from the law on which this coefficient is based must be an error. Upon this ground, then, the assumption of an error as regards the power exerted in the Viper and Vixen is disproved, because the coefficient for the Philomel is lower than that for these vessels, being 419 against 439 and 433 —a very material amount of difference. Why the Philomel class have so low a coefficient does not affect the question, and need not be entered on here.

To return to the fact that the results of the trials of the Waterwitch at Stokes Bay, which were officially reported from Portsmouth, and which were accepted at the Admiralty as correct, placed her performances, as before stated, nearly on a par with the screw in the sister vessels, Viper and Vixen, with which she was built to compete ; it is desired by some to look upon these results now as not conclusive evidence in favor of the turbine, but she certainly would not have been built in her present form if there had been any obvious reason why the comparison between her and the Viper and Vixen would not be a satisfactory test. None of the parties interested made any objections at that time. It is greatly to be regretted that all these vessels, both turbine and screw, should have turned out unfit to be kept in commission, and used along the coast, but even with the Waterwitch, such as she is, many interesting experiments might be made, and, indeed, ought to be made, if I may be permitted to say so, before another turbine ship is attempted, as many modifications present themselves as worthy of trial.

The mode of introducing the water into the vessel has been a subject of comment and discussion, but there seem to be good reasons for believing that the introduction of it at the bottom by slits sloping upwards into a canal, as in the Waterwitch, is to be preferred to an entrance at the bow of the vessel, or at the sides. The only objection that has been urged with much show of reason has been, that the proper supply of water might be interfered with if the vessel took the ground on a flat shore, with stiff or gravelly clay under her; but this is an occurrence of so exceptional a character, that it need scarcely influence so important a point for her general employment, and there would probably be a better chance of getting her off from such a position by laying out an anchor and hauling upon it, than by working the engines and getting so small a pull upon her as we have previously shown they would give under such circumstances. A proposal has also been lately made by the Chief Engineer of the Italian Government, who takes a favorable view of the system theoretically, to introduce the water from abaft; but it is to be feared that the speed of the vessel through the water would not allow time for the limited pressure of the water outside to force a sufficient supply into the passages, even though the pump created a vacuum for it to flow into. The present arrangement also gives facilities for sluices to admit a large supply of water from the interior of the ship, in the event of a leak, as well as for stopping off the supply from the sea when the turbine is not at work.

The form of the turbine itself, however, is the most important question. It has been already stated that the efficiency of different centrifugal pumps has been found to vary as much as 25 per cent. In the Waterwitch, the blades of the turbine are made to curve in exactly the opposite direction to those in Appold's pumps and in the most approved pumps of the present day, and though these were so made, under the patentee's express instructions, as he considered it the best form, it would be most important to have a new set of arms or blades made with the curvature, and to test the effect, more especially as this could be done without altering the outside case and the work connected with it, and would consequently be comparatively inexpensive.

If the views respecting the pump as a propeller, as previously expressed, be correct, and the pump be made thoroughly efficient, so as to bring into useful effect a large percentage of the power brought to bear upon it by the steam-engine, then the propeller must be also efficient by the law of science, that action and reaction are equal, that is, "that the total momenta impressed by any force in one direction must be looked for by equivalents, to reappear in inverted momenta in the opposite direction." These are the words of Mr. Reed, at the Naval Architects' Institution, when arguing upon a paper by Professor Rankine, who replies, "that the whole of his paper is founded on that very dynamical principle to which Mr. Reed refers, in combination with another principle, as the oscillatory character of wave motion."* This definition of reaction is quoted as being clear, and specially applicable to the turbine, and the reply is referred to as an instance of the difficulty that even scientific men find in understanding and following deep mathematical investigations of this kind made by themselves, as previously referred to in this paper.

The vertical position of the shaft of the turbine is a great drawback to the application of engines of ordinary construction, but it is by no means improbable that a pump may yet be made with the shaft running horizontally, and this would undoubtedly remove much of the hesitation of engineers to recommend the principle to their clients the shipowners for a trial.

The form and size of the discharge nozzles might also be experimented on with advantage. There seem to be grounds for believing that a very much larger orifice would give a greater propelling power, though attended with diminution of pressure. Centrifugal pumps have not been found good for high lifts, from which it may be inferred that it is difficult to obtain pressure in them, and their efficiency is best displayed in the large quantities of water which they deliver at a moderate height of the power employed. There are difficulties in the way of enlarging the nozzles of the Waterwitch to test this, but there would be none in reducing them, and trying the effect, testing the pressure and the actual velocity of the water with the different sized nozzles.

* Transactions of Naval Architects' Institution, 1867, page 99.

It is believed that this velocity has never yet been tested, and that all the calculations as to the number of tons of water discharged have been made from an assumed velocity, founded on the speed of the blades of the pump.

It does not necessarily follow that the pressure will be increased by making the orifice smaller, because if the discharge be not sufficiently free after a certain pressure has been attained, the water will remain in the pump, and revolve with the blades, or lie dormant in the space between the ends of the blades and the casing. This is found to be the case with fan-blowers, the steam-engine running faster, showing less resistance and less work done when the escape of the full quantity of air is prevented by lessening the orifice for its exit.

It has been assumed by some that the speed of the effluent current at the nozzle ought to be about 10 per cent. above the speed that previous calculation would give to the ship, but further experiment is required before this can be received in any way as definite or as a best proportion of one to the other.

The height of the orifice above the water is also a question that is open to discussion, but there do not appear to be grounds for believing that there would be any important advantage in placing it below water, and if this be the case there are certainly great practical advantages in continuing it above water, where it can be got at with facility, and by which the pump can be kept empty. When the orifice is near the surface of the water, no power of any consequence is lost in raising it, as it will of itself rise in the pump to the level of the water outside.

While the experiments that have been herein proposed would be important, the alteration that one would most wish to see carried out in the Waterwitch would be to put a new bow and a new stern to her, and raise upon her. This would leave all the most expensive part of the ship, with the machinery in it, untouched, or if the ship were merely raised upon with skeleton work, as was done with the Cerberus, to make her seaworthy, much useful information might be obtained.

The further advantages of the turbine propeller in stopping the way of a vessel rapidly, at the command, and under the hand of the officer in charge, as well as its great power over a heavy leak, its freedom from the chance of internal injury and of being fouled, and the comparative ease with which it can be protected from shot, have all been brought before the Institution in the paper formerly read, and they appear to be admitted.

The power of the turbine propeller to turn a vessel round with rapidity has disappointed its advocates to some extent on this point, but it has been proved that a vessel's steerage is very much assisted by it, and in the case of the very long ship now being introduced into the merchant service, as sailing and steaming clippers, the assistance that it will render in enabling their heads to be kept to the sea, and preventing them from falling into the trough of the sea, will be very important, and make it not only equal, but superior, to the twin screw system in this respect, as the captain can manage the whole as easily as he can the steering wheel.

For vessels of light draught, especially of large size, such as are required for the Danube, the Volga, the Ganges, or the Indus, and others, the turbine has been put forward as specially applicable, but the paddle-wheel may compete with it for speed in these, and it must rely on its own intrinsic merits, and not on the inapplicability of other systems of propulsion, for its adoption in these as in other vessels.

Its advantage in combination with sails, though previously mentioned, may perhaps be dwelt upon a little further, as this has not perhaps been done to the extent that it might have been by its able advocate Admiral Elliot, in his anxiety to show its peculiar fitness for small vessels for end on fighting with a rudder in the bow and prepared to steam either way. In speaking of this point for a man-of-war cruiser or for a merchant ship making a long voyage, it is not merely that the action will be better in a sea-way from its not being affected by the pitching or rolling of the vessel, or that it does not interfere with any form that it may be desired to give to a vessel to insure good sailing properties, nor yet that it can be brought into action or its use discontinued at pleasure with facility, but that if the ship be going 10 knots or even more under canvas alone, at which time the screw or the paddle would be of little or no service, it is believed that the turbine could at such a time be used with full effect, and that a speed would be obtained greater than has ever yet been realized on the ocean. Differential gear to suit the speed of the screw to the speed of the ship when under canvas, and feathering the blades of the screw to attain the same object by altering the pitch, have been tried, but have not as yet been adopted to such an extent perhaps as they may deserve; but no such alteration is required for this purpose with the turbine. The water when taken into the turbine acquires the velocity of the ship at whatever speed she may be going, and that forward motion is communicated to it quite irrespective of the circular motion and centrifugal velocity given to it by the pump; the whole, to use a technical phrase, being self-contained. Now, in the same manner as a man can throw a weight the same distance from the bow towards the stern of a ship in motion (practically speaking) at whatever speed the ship is going, so the turbine will always throw the water out from the nozzle at the velocity due to the action of the pump, and obtain from the recoil the same forward pressure, whatever the speed of the ship may be, and this pressure will produce a corresponding effect in increasing the speed of the ship. If this be correct, it will enchance the value of the hydraulic system of propulsion very much, and it seems to afford additional grounds for urging further trials. The machinery of the "Waterwitch" has been in all respects satisfactory, and reflects great credit on Messrs. Dudgeon, the manufacturers; and if a duplicate of it were to be contracted for, and put into an iron vessel of the Philomel class, which was designed with a view of being a small cruising vessel, good relative results as to speed can be guaranteed as a matter of course after the results in the Waterwitch, and an opportunity would be afforded of further trials of many kinds. When the screw was first introduced, the Rattler was kept under trial for many months, to determine the length of screw necessary for efficient effect, beginning with a long screw, and gradually reducing it with beneficial results, to the astonishment, I believe I may say of all, till it had been shortened to one-sixth of the pitch, after which the effect was found to diminish; and a further series of trials were made to determine whether screws of coarse or of fine pitch were most advantageous. The expense of these trials must have been considerable, as the ship had to be docked on every occasion of cutting the screw or putting on a different screw; but that it was a wise and prudent expenditure, was amply proved by the success of the screw ships that immediately followed; engineers having been thus enabled to proceed with confidence in designing and constructing the screws and machinery for them.

In advocating for the turbine an extension of the trials that have been commenced, these early trials of the screw may be quoted as having been of immense benefit to the country, leading to the fact of our Navy being placed on a superior footing to that of other nations for many years at that time. As evidence of the superiority, an expression of the late Admiral Sir Henry Chads, who was at first most inimical to the introduction of the screw into our men-of-war, and who was sent to cruise in the Edinburgh, block ship, to test her qualities, may be quoted, as on his return the writer of this paper heard him say to Lord Auckland, who was then Frst Lord of the Admiralty: "My Lord, if there was a war to-morrow, and you gave me my choice of all the ships in the Navy to command, I would ask for the Edinburgh."

The experiments in the Rattler were of further benefit to the country as regards the mercantile service, by enabling the manufacturers of her machinery to construct at once, with certainty, useful and profitable screw merchantmen, showing the wisdom of the Admiralty in fostering an invention that might prove an aid to national industry and wealth.

It is to be hoped, then, that the Admiralty of the present day, viewing a first expense as a true economy, may be induced to bestow the same fostering care on this new system as was done by their predecessors (amongst whom, from my own personal knowledge, I would especially wish to name Sir George Cockburn, Sir Charles Adams, Mr. Sidney Herbert, and Mr. Corry) on the screw when it was in its infancy, and follow with regard to the turbine the same enlightened and true policy of full and exhaustive experiment, and then allow it to fall or rise on its merits.

WATER SUPPLY OF GLASGOW.

From "The Engineer."

The extent to which the literature bearing upon the water supply of large cities has accumulated during the last 30 or 40 years is one of the most convincing and practical illustrations of the importance of the snbject that could be adduced. Sanitary reformers and civil engineers are more and more accustomed to turn their attention to the necessity of a pure, wholesome, and sufficient water supply, and the means whereby it can be provided. When any epidemic breaks out, the quality of the water used by those infected is the first subject of investigation, and exactly in proportion as the water supply is pure and abundant, will the liability to disease be found to diminish. It is not surprising, therefore, that municipal corporations vie with each other in securing the best possible facilities for the possession of this indispensable adjunct to health and comfort; and it is gratifying to find, also, that measures are being proposed and carried out for acquiring a pure and plentiful supply, regardless of cost.

Glasgow was long destitute of anything like a proper water supply, a large proportion of water used previous to the completion of the Loch Katrine scheme, having been obtained from the Clyde—then, as now, one of the most polluted rivers in the kingdom. The evil under which the citizens of St. Mungo so long labored in this respect was all the more inexcusable, seeing that an almost illimitable source of supply lay at their very doors. Ultimately, although not for some time, that source of supply was made available, and from thenceforth Glasgow enjoyed the privilege and credit of having the most ample and efficient water supply of any town in the three kingdoms. With the circumstances which led to the projection of the Loch Katrine Water Works our readers are no doubt familiar. The magnitude of the scheme may be estimated by the fact that the Works were originally designed on a scale sufficient to supply the city with 50,000,000 gallons a day. The built portions of the aqueduct, with all the tunnels and bridges on the line, were constructed at first of sufficient dimensions to pass this enormous quantity. From the first the storage provided in the lochs was sufficient to insure the constant supply of 50,000,000 gallons a day to the city, and of 40,500,000 gallons a day of compensation water to the river Leith—making a total of 90,500,000 gallons per day. The cast-iron troughs which form portions of the bridges on the first 11 miles of the aqueduct, and the pipes across the Valleys of the Duchray, the Endrick, and the Blane, on the line of the aqueduct, were, however, put down of a size to supply only 20,000,000 gallons per day, because these portions of the works were capable of easy extension as the requirements of the city expanded. When the Glasgow Town Council first resolved in 1852 to take the water supply into their own hands the quantity of water supplied to the city by the two companies then in existence was 14,000,000 gallons per day, being somewhat less than 40 gallons per head per day. This allowance was adopted as the basis of Mr. Bateman's calculations when designing the Loch Katrine Works in 1853-4, and it was then considered to be much in excess of actual requirements. Subsequent, however, to the introduction of the Loch Katrine supply, the consumption rose considerably above 40 gallons per head per day; and so rapidly did the increase continue that in 1864 the quantity of water drawn by the city from Loch Katrine was 19,000,000 gallons a day, and the average consumption per individual was 47 gallons per day. The extension of the water-closet system throughout the city has greatly contributed to this increase of consumption; but there are other causes scarcely so apparent. Of the three largest cities in the empire, we find that London had in 1868 441,000 water-closets, or one for every six persons; Liverpool had 25,000, or one for every 24 persons; while Glasgow had 28,000, or one for every 17 persons. During the three years that have elapsed since that time we believe the water-closet system has been extended more generally in Glasgow than in either of the other two cities with which it is here brought into comparison. The great increase of consumption involved the necessity of taking measures some 4 or 5 years ago to provide an additional supply. The extension of the water-pipes to a number of outlying villages and districts operated in the same direction. Indeed, since 1860 the Water Commissioners have extended the Loch Katrine supply to Maryhill, Springburn, Thornliebank, Nitshill, Barrhead, and Harlet; and further extensions have been made to Rutherglen, Shettleston, Cathcart, and other suburbs of the city. An addition of 2½ ft. was made to the cast-iron troughs forming part of the aqueduct bridges at the time already mentioned, making the total depth of these structures 6 ft. 6 in., while the breadth is 8 ft., so that they are now sufficient to convey the full 50,000,000 gallons a day.

The following tabulated statement will show the gradually increased supply of water sent into the city from the Commissioner's works during the period in question:—

YEAR.	Quantity sent into the city daily.	Daily consumption per head.
	Gallons.	
1861	18,610,000	42.6
1862	19,630,000	42.9
1863	20,170,000	42.3
1864	22,530,000	46.8
1865	23,060,000	47.0
1866	23,770,000	47.4
1867	27,020,000	52.9
1868	25,400,000	48.9

It will be remembered that the population had increased from 436,900 in 1861 to 518,960 in 1868, and at the present time, with a population of 550,000, the quantity of water sent into the city daily is 28,000,000 gallons, or about 50 gallons per head per day. The steady growth of consumption has called forth in several quarters animadversions as to the waste of the supply. Mr. Gale, the able engineer of the Glasgow Water Works, in a paper "On the Distribution of Water in Glasgow," read at a meeting of the Institution of Engineers in Scotland, on the 16th of March, 1864, after showing that the quantity of water used daily for domestic purposes in Glasgow was just 26 gallons per head daily in 1838, as compared with 35 gallons in 1852, and 39 gallons in 1863, proceeds to argue that the great increase of consumption of water in Glasgow is due in a great measure to waste from imperfect fittings; that, in fact, a quantity amounting to 15 gallons per head per day runs to waste without benefiting any one.

We have reason to believe that measures will be adopted before long to get rid of this extravagant waste, and thereby to reduce the water assessment of the city. It is a noteworthy fact that the average consumption of all the large cities in England, representing a population of 6,000,000, is under 30 gallons per head per day, or fully 20 gallons per head per day less than the average of Glasgow. The average consumption of the large towns of Scotland is considerably over that of the large cities in England. Edinburgh and Aberdeen average about 40 gallons; Greenock runs up to between 60 and 70 gallons; while Glasgow, as we have already indicated, comes in between with an average of 50 gallons per head daily. The waste in Greenock is easily accounted for, there being a superabundant supply for the wants of a limited population.

The consumption of water in Glasgow is increasing at such a rapid rate, that in order to meet the wants of the population it has become necessary to make further provision for increasing the supply, and tenders are now being advertised "for the laying and jointing of two lines of 36 in. cast-iron pipes from the self-acting valves near Mugdock Reservoir to a point opposite Chapelton Farm-house, near Canniesburn Toll-bar." At present there are only two lines of 36 in. pipes from Mugdock Reservoir, which is about 7 miles from the city. These pipes are calculated conjointly to deliver 25,000,000 gallons per day, being one-half the quantity of water which the Commissioners are empowered by Act of Parliament to draw from Loch Katrine. During last summer these pipes were delivering 28,000,000 gallons per day, or 3,000,000 gallons in excess of their due capacity. So that it has become necessary to lay additional pipes from Mugdock Reservoir, which will be done under the Parliamentary powers, obtained when the works were originally designed. In the mean time, the extra mains will only be carried as far as Canniesburn toll, or about half way between Mugdock and the city, leaving the prolongation of the work to be executed as the requirements of the city may demand.

It is estimated, however, that the works to be undertaken during the ensuing summer will, considering the high price of pig iron, cost not less than £50,000, while the completion of the mains to the city, which will probably be undertaken in the course of two or three years hence, will involve an additional £80,000. We may add that it will shortly be necessary likewise to lay some additional pipes across the valleys of the line of aqueduct from Loch Katrine; but this work, which will certainly not cost less than £50,000 more, can afford to wait for some years yet, even although we take into consideration the startling fact that the population of the city is increasing at the rate of 1,000 per month.

ON THE HYDRAULIC RAM.

By W. J. MACQUORN RANKINE, C. E., LL.D., F.R.S.

From "The Engineer."

The most complete body of information respecting hydraulic rams is that contained in a treatise on the subject published by Eytelwein, about 1808, and stating the results of a very long series of experiments. The conclusions at which he arrives may be summed up as follows:—Let h be the head of pressure, in feet of water above the level of the pond, against which the water is to be forced into the air vessel, H the depth of the waste-valve below top-water in the pond, Q the volume of water run to waste in a second, q the volume of water lifted per second, L the length of the feed-pipe in feet, D its diameter in inches, d the diameter of rising pipe; then the best dimensions are

$$D=\sqrt{235(Q+q)};\ L=h+\frac{2h}{H};\ d=\frac{D}{2};$$

the area of opening of each of the valves to be equal to that of the feed-pipe, the valves to be as light and as near each other as possible, the air vessel to have a capacity equal to that of the feed-pipe.

When these rules are observed, the efficiency, as found by Eytelwein's experiments, is given for values of $h \div H$, ranging from 1 to 20, by the following empirical formula:

$$\frac{q\,h}{Q\,h}=1.12-0.2\sqrt{\left(\frac{h}{H}\right)};$$

I have found, besides, that when $h \div H$ *does not exceed* 12, the results of Eytelwein's experiments are very well represented by the following more simple formula for the *counter-efficiency* (that is, the reciprocal of the efficiency):

$$\frac{Q\,H}{q\,h}=1+\frac{h}{10\,H};$$

in which the second term represents this *work wasted* for each unit of useful work.

From practical trials it appears that if a feed-pipe of less diameter than that given by Eytelwein's rules is employed the length must be increased, in order that the horizontal column of water may have sufficient momentum. For instance, in a case described to me by an eminent firm of mechanical engineers the diameter of the feed-pipe was about one fourth, and the length about double, of the respective dimensions given by Eytelwein's rules.

It is probable, moreover, that when a longer and narrower feed-pipe than that given by Eytelwein's rules is employed, the work wasted is increased nearly as the length directly, and as the diameter of the pipe inversely, such being the approximate law of the resistance of pipes.

In the case just referred to, the counter-efficiency with Eytelwein's dimensions, and according to his rule, would have been 1.29. It was actually about 3.15; so that the loss of work was increased in the proportion $\frac{2.15}{0.29}=7.4:1$; which nearly agrees with the before-mentioned supposition.

Extraction of Metallic Antimony.—A new method of obtaining metallic antimony from the ore is as follows: The ore is pulverized and treated in wooden vessels with hot hydrochloric acid. The antimony is precipitated from the solution by means of zinc or iron, and the precipitate washed, dried, and melted in a crucible under a covering of charcoal dust.

PNEUMATIC TRANSMISSION.

By FREDERIC CHARLES DANVERS, A. I. C. E.

From the "Quarterly Journal of Science."

The practical application of air to the transmission of carriages on land dates only from the commencement of the present century. The first idea, however, of transmitting power to a distance by means of pneumatic pressure, appears to have originated with the celebrated Denys Papin, a Frenchman, who, in 1688, described an apparatus in which a partial vacuum produced in a long tube, by air-pumps fixed at one end, caused the motion of pistons at the other end; but no record remains to prove that any steps were taken by Papin to carry his suggestions into effect so as to derive any useful practical advantage from them. The introduction of the locomotive engine naturally directed the attention of engineers and others to the subject of the provision of improved means of communication, and this desire was doubtless stimulated by the acknowledged defects of the locomotive at that time, and its reputed inapplicability for lines with gradients exceeding 1 in 100. The first person to introduce the atmosperic system of propulsion was a mechanical engineer named George Medhurst, who, in 1810, published a pamphlet on the subject, entitled "A New Method of Conveying Letters and Goods with Great Certainty and Rapidity by Air," in which may be recognized the first practical suggestions for the introduction of what is now known as the "Pneumatic System;" and it is not a little surprising to find that in this, and two subsequent pamphlets by the same author, are foreshadowed almost everything that has hitherto been discovered in connection with this subject—all subsequent inventions having reference merely to the detailed means for carrying that system into effect.

George Medhurst's first idea clearly was to employ the pneumatic system for the conveyance of small parcels only, but he subsequently suggested its application for the transport of goods of a more bulky nature. It is perhaps a pity that he did not confine his attention in the first instance to the development of his earliest ideas on the subject, and which has subsequently been proved to be the most practical method of applying his invention, viz., for the transmission of letters and small parcels. The rage of the day being, however, for improved means of communication, it is not surprising that his own ambition and the popular clamor should have caused Medhurst to endeavor to apply his invention to a purpose for which it was ill-suited. We shall not now follow the progress of the gradual rise and fall of the atmospheric railway, from the time when John Vallance, in the year 1826, constructed a model tunnel in Devonshire Place, Brighton, 120 ft. long, and nearly 8 ft. in diameter, through which a carriage was propelled by means of air-pumps worked by two steam engines, which was the first of its kind ever constructed, to the abandonment of the atmospheric principle upon the Paris and St. Germains line for the last mile and-a-half of its length, which was taken up in the year 1860, after having been in successful operation for about 15 years. From this last named circumstance it is clear that the atmospheric system is not wholly unsuited for railways under certain circumstances, the chief ground of its applicability being upon very steep inclines, such as were unsuited for locomotives. The inconvenience, however, of having different systems of propulsion upon the same railway has been the cause which has led to the abandonment of the atmospheric principle upon every railway where it has ever been tried; the general advantages, greater speed, and undoubted superiority of the locomotive gaining for it, in every case, the preference over the latter.

Thus ended all attempts to introduce atmospheric railways; but a few years before their final abandonment the adaptation of the principle for the transmission of small parcels was again revived, and it now seems likely to come into very general use, especially in connection with the Post Office and the Telegraphs. The want of some means of speedy communication between the offices of the Electric and International Telegraph Company in London, in addition to that afforded by their lines of wire, probably led to the invention of a pneumatic tube for that purpose by Mr. Latimer Clark, and the first tube was laid down by that Company in 1855. This tube was of lead, and the carrier (in which messages were placed) nearly fitted the bore, and was covered with felt. It turned out to be a complete success, and a similar principle was adopted by the Prussian Telegraph Administration in Berlin, between the Telegraph Office and Exchange, in the year 1863; in 1866 it was also adopted in Paris in connection with the Electric Telegraph stations in that city. Later still the principle has been introduced into New York, and quite recently a line has been laid down by Messrs. Siemens, in connection with the General Post Office in London, for the conveyance of messages in original between Telegraph street and Charing Cross and on to the House of Commons, instead of sending them by Telegraph.

There are two methods which have at different times been adopted for impelling carriers through pneumatic tubes, the one being by creating a vacuum in front of the carrier, which is then impelled forward by the atmospheric pressure with a force equal to the difference between the latter and the vacuum. The other is by creating a "plenum" behind the carrier, or, in other words, increasing the pressure behind the carrier beyond that of the atmosphere, the difference between these two forces in pounds or ounces per square inch representing the force expended in driving the carrier through the tube. Medhurst, in his first invention, adopted the latter principle, and the introduction of the vacuum for the purpose is ascribed to John Vallance, who proposed it in a pamphlet published by him in 1824. Experience has shown that the vacuum is the far preferable manner of working pneumatic tubes, and it is also more economical than working with a plenum.

The difference between the effects of compression and exhaustion would appear, so far as recorded experiments upon the subject show, to vary in the cases of tubes of different diameters; but, as a general rule, it has been observed that when a carrier is inserted into a tube it is driven forwards with a mean velocity corresponding to that with which the air at the higher pressure is introduced behind it, or that at the lower pressure is exhausted in front of it. In a paper read before the British Association at Liverpool last year by Mr. Robert Sabine, that gentleman has worked out a number of formulæ for calculating the work performed in pneumatic tubes, and the result of his investigations on this subject cannot fail to be of great value, as it is one upon which very little of scientific value has hitherto been published. "The problem of a successful pneumatic system," says Sabine, "is simply this: To make a given quantity of air expand from one pressure to another in such a way as to return a fair equivalent of the work expended in compressing it. It is obviously impossible to regain the full equivalent of the work, because the compression is attended with the liberation of heat, which is dissipated and practically lost to us. Therefore, in designing a pneumatic system, that which we have to do is first to contrive means of compressing the air as economically as possible; secondly, to get back as much as we can of the mechanical effect stored up in our already compressed air, irrespectively of the work which was employed in compressing it. The utmost theoretical work which a given quantity of air can be made to perform is evidently that of expanding from the higher to lower pressure; and the mechanical effect employed in propelling a carrier and air through a given tube is therefore equivalent to that due to the expansion of a tubeful of air from the higher to the lower pressure." The speed at which a carrier travels in a horizontal tube has been worked out by Sabine, and is expressed by the following equation:—

$$s = \sqrt{2g \frac{vf - Wl\mu}{W + \frac{w_1 + w_2}{2} v \left(1 + \zeta \frac{1}{d}\right)}} \text{ ft. per sec.}$$

But when going up or down an incline—

$$s = \sqrt{2g \frac{vf - Wl(\sin a + \mu \cos a)}{W + \frac{w_1 + w_2}{2} v \left(1 + \zeta \frac{1}{d}\right)}} \text{ ft. per sec.}$$

In these equations the volume of the tube in cubic feet is represented by v; l represents the length of the tube in feet, and d its diameter also in feet; W is the weight of the carrier in pounds, and g the accelerated motion due to gravity; f represents the mechanical effect performed by 1 cubic ft. of air; μ, the coefficient of friction of motion of the carrier in the tube; w_1 the weight in pounds of 1 cubic ft. of air at the higher pressure; w_2 the weight of a cubic foot at the lower pressure ; and a the angle made by the tube with the horizon, and which is + when the carrier ascends, but — when it descends. ζ is an empirical constant ; experiments to determine its value have been made by Girard, D'Aubuisson, Buff, Pecqueur, and others, who give a mean value for it of 0.02.

Dr. P. Brix, Professor at the Bau-Akademie, has published in the German "Telegraph Journal" particulars of experiments made by him upon velocity with a tube $2\frac{1}{2}$ in. in diameter, laid down some years ago by Messrs. Siemens at Berlin, between the Exchange and Central Telegraph Station, the results of which were that when working with compression the tension of the air at either end of the tube was 19.31 lbs. and 14.75 lbs., and with exhaustion, 14.75 lbs. and 10.19 lbs., respectively; the mechanical effect produced by 1 cubic ft. of air in each case was 512.17 lbs in the former, and 520.44 lbs. in the latter ; and the weight of the air at the two extreme tensions, was, in compression, 0.1099 and 0.0753 foot-pounds, and in exhaustion 0.0752 and 0.0447 foot-pounds. For each case the frictional resistance of the carriers in the tube averaged 0.1 lb.; the length 2,920 ft. for each half of the tube ; its diameter 0.193 ft.; and its volume, 85.49 cubic ft. With these values, the formula worked out by Sabine gives the calculated speeds in these two experiments as follows :—With compression, 34.1 ft., and with exhaustion 43.2 ft. per sec., or that the carrier should have occupied in the transit from station to station, in the former case 86 secs., and in the latter 68 secs., differing from the observations made by Dr. Brix 9 secs. in the one case, and only 2 secs. in the other. This difference, Sabine thinks, may possibly be due to an error of observation of the pressure, or possibly to the fact that the constant ζ may not be the same for small welded iron tubes as for a large cast-iron tunnel.

Mr. Sabine has also made some experiments with the tube of the Pneumatic Company between Euston Station and High Holborn, which was some years ago designed by, and carried out under the engineering superintendence of, Mr. Rammell and Mr. Latimer Clark. This tube is ⌓-shaped, $4\frac{1}{2}$ ft. broad and 4 ft. high. The trains used were each made up of 3 trucks, and these were loaded with an average weight of 6 tons, making, with the carriages, a gross load of 9 tons. The average time occupied in running through the tube from Euston Station to Holborn was $7\frac{1}{2}$ min. with a partial vacuum of 5 oz. per sq. in., whilst the empty trucks were returned to Euston Station with a compression of 5 oz. per sq. in. in $6\frac{1}{2}$ min. Assuming the temperature of the air to have been 20 deg. C., and its mean pressure 14.75 lbs., it is calculated that in drawing the loads through to Holborn the air was exhausted to 14.44 lbs., and in sending back the empty carriers it was compressed to 15.06 lbs. per sq. in. From these data the mechanical effect due to the expansion of 1 cubic ft. of air in the two experiments has been deduced to have been 31.964 foot-pounds with exhaustion, and 31.945 foot-pounds with compression.

In employing the same amount of mechanical effect, and the air remaining of the same mean specific gravity, Sabine finds "that the mean speed of transmission varies inversely with the length, and inversely also with the square root of the diameter of the tube. Thus, with an equal mechanical effect expended upon it in each case, a very light piston would travel through a tube of 1 mile long with exactly twice the speed with which it would travel through a similar tube 2 miles long. And further, if we had two tubes, each 1 mile long, one having a diameter of 4 ft. and the other a diameter of 1 ft., the air in the larger tube would only travel half as fast as that in the smaller one, assuming, of course, the total work performed during the transit to be in each case equal. The cause of this is simply that the greater portion of the mechanical effect which in the larger tube is used for moving the greater mass of air, is, in the smaller one, converted into speed. If the case arose, therefore, that a pneumatic transit had to be made with a stated expenditure of work, we should proceed economically by adopting a tube of small rather than one of large sectional area. With an equal utilized engine power in each case, the mean speeds of transit of air through two tubes are inversely as the cube roots of their diameters and lengths. For instance, with a utilized effect of 10-horse power, the velocity of transit in a tube 8 miles long, being 20 ft. per sec., that attainable with the same power in a 1 mile length of the same tube would be 40 ft., and if we had two tubes of equal length—one 8 times the diameter of the other—the speed attained in the larger tube would be only half that attained in the former. To obtain the same speed of transit of a very light piston in two tubes of equal length and different diameters, other things being equal, the utilized horse-power must be directly proportioned to the diameter, whilst to produce the same mean speed of transit of very light pistons in tubes of equal diameter but different lengths, other things being equal, the utilized horse-powers of engines may be taken as directly proportional to the lengths. Similarly, when the lengths and diameters are equal, but the mean specific gravity of air in the two operations are different, the mean speed of a very light piston being the same in its transits through the same tube, or through two tubes of equal dimensions, the utilized engine power is directly proportionate to the mean specific gravity of the air on the two sides of the piston. It follows from this, therefore, that in working by exhaustion less engine power is required, other things being equal, than in working through the same tube by means of compression. And it would also follow that in hot weather, and when the barometer is low, the working of a pneumatic tube should be less costly in engine power than in cold weather and when the barometer is high.

"With given utilized horse-power operating upon a given line, the velocity of a very light carrier would be reciprocally proportional to the cube root of the mean specific gravity of the air moving in it. Mr. Siemens has proposed to take advantage of this fact by the employment of hydrogen gas for propulsion in letter tubes instead of atmospheric air. The specific gravity of hydrogen is 0.07; that of air being 1. The speed attainable, therefore, by the substitution of this gas would be as—

$$1 : \frac{1}{\sqrt[3]{0.07}}, \text{ or as 1 to } 2\tfrac{1}{2} \text{ nearly.}$$

This plan would be easily practicable with Messrs. Siemens' system of complete circuit tubes, in which the same air is pumped round without being changed. With any of the ordinary systems by which the tube is open at one end, of course only the atmospheric air could be used in practice."

A by no means unimportant matter in connection with the working of pneumatic tubes is the mechanical means employed for producing the vacuum or plenum, as the case may be. Several methods have been introduced with this object. The first system adopted by Vallance in his model at Brighton, in 1828, was to produce the vacuum by means of air-pumps worked by two steam engines, and this was the plan afterwards most generally employed on the several experimental lines of pneumatic railway laid down in different parts of the United Kingdom and elsewhere. In the Prussian pneumatic despatch tube both compression and expansion are employed. The tube itself consists of two tubes of welded iron 2½ in. internal diameter, laid parallel to one another beneath the pavement. A transverse coupling connects them together at one end, whilst at the other end they terminate in two reservoirs, between which an air-pump exhausts the air from one and compresses it into the other, thus keeping up a continual circuit of current within the tubes.

The pneumatic system in use in Paris differs from the foregoing principally in the use of water-power instead of steam-engine power for working the tubes, each station being supplied with an arrangement for compressing air. Until recently the transmission of carriers between stations was effected by means of compression alone, produced by the action of water upon a chamber full of atmospheric air. This water is obtained from the River Ourcq, and is employed in the following manner:—Three wrought-iron cylindrical vessels are erected at each station, one of which is large and the other two smaller, and of the same size as one another. The larger vessel is connected by means of a pipe with the water mains of the town, and an exhaust pipe leads from the same vessel into the sewers; each of these pipes is fitted with a valve to enable the communication to be opened and closed at pleasure. From the top of this vessel a pipe leads into the first of the two smaller reservoirs, and these again are connected together by a pipe fitted with a cock, whilst the second smaller reservoir is in communication with the pneumatic transmitter. In order to obtain a supply of compressed air, the valve is closed in the tube communicating with the sewers, and that leading to the water mains is opened, allowing the supply of water to rush into the larger vessel, and to displace the air which previously filled it. This displaced air is compressed into the two smaller reservoirs until the water has risen nearly up to the top of the larger vessel. A cock, in the pipe communicating between that and the smaller reservoirs is then closed to prevent the air returning. The water is then run out of the larger vessel into the sewers, and it again becomes filled with air, which is in turn compressed into the reservoirs as before, as soon as it is required.

The Pneumatic Dispatch Company in London employ a pair of horizontal engines to drive a fan 22 ft. in diameter, by means of which the air can either be exhausted from, or forced into, the tubes at pleasure.

The latest form of pneumatic tube is that recently laid down by Mr. Siemens, from the Post Office in St. Martins-le-Grand towards Westminster, and which will probably be extended, in course of time, in other directions. Several entirely new features have been introduced in the construction of this tube, which we shall describe more fully at some future time in our chronicles of engineering, when the system has become more perfected than it is at present. One new feature which Mr. Siemens proposes to introduce is a novel kind of blower, which he has designed, to be worked direct by the steam from a boiler, without the intervention of machinery, and which will not only effect a considerable saving in the first cost of the requirements of each station, but it will also be much more economical in working and for maintenance.

The methods adopted at the different stations on any pneumatic line differ, of course, with the various methods employed for transmission, and it is in this that very great improvements have recently been introduced by Mr. Siemens. We have stated that in the Berlin pneumatic despatch system two tubes are placed parallel to each other, and connected together at one end by a transverse coupling, whilst at the other they terminate in two reservoirs, between which an air-pump exhausts the air from one and compresses it into the other, by which means a continual circuit is maintained, and provision is made for the despatch of messages in either direction. The tube for transmitting a carrier from any station is connected with the pressure reservoir, beyond which connection it is continued at a slight incline in which are placed two cocks, at an interval equal to the length of the carrier. Beyond the second cock the tube is open at the top in the form of a trough, into which the carrier is first placed. The first cock is then opened, allowing it to pass down the tube as far as the second cock. The former is then closed again and the latter opened, whereupon the carrier descends the inclined tube until it passes the pipe communicating with the pressure reservoir, whereupon it is caught by the current of air and blown to its destination. These carriers are thin metal cylinders, nearly filling the tube, supported by 4 wheels, 2 at each end, and alternately at right angles to each other. The receptor consists of a square box placed in continuation of the tube connected with the exhaust reservoir, with which it communicates by means of a cock bored to the same diameter as the tube itself. This box is lined with brushes, through which the carrier forces its way, and its impetus is thus checked, whilst at the extreme end is an india-rubber buffer. The Exchange station, at the other end of the tube, is supplied with similar apparatus, only, of course, without the engine, pump, etc.; instead of which the tubes are connected together by a short coupling tube. In some experiments which were made to determine the relative pressures in the two reservoirs, it was found that with equal differences of 9 in. of mercury above and below atmospheric pressure, the transit time of a carrier the whole distance of 3,000 ft. was 95 secs. from the station to the Exchange, whilst it only occupied 70 secs. in returning. The pressures now employed are, in the one reservoir, 7 in. of mercury over, and in the other 6 in. under atmospheric pressure. With this arrangement the transit times were, from station to Exchange 1 min. 30 secs.; and from Exchange to station 1 min. 20 secs.

In the system in use in Paris the same apparatus constitutes both the receptor and transmitter for the carriers. It consists of a cast-iron stand or pedestal, surmounted by an air-tight box, in front of which is a lid or door. Two tubes enter this box from opposite sides ; one leading to the pressure reservoirs and communicating, through a cock or valve, with a branch below it, with the box, whilst the other branch from the box is connected with a tube open to the air at the top, and also provided with a cock. A central vertical tube closed at the top is used when the carriers arrive, and acts then as an air buffer, against which they expend their force. Beneath the box another tube leads to the next station. In sending a message it is placed in a box and the door shut, the cock communicating with the compression reservoirs is then opened, and the pressure of air blows the carrier through the tube. At this time the cock communicating with the open tube is kept closed, but when a message is to be received this cock is opened and the other kept closed—the open tube admitting the escape of the air in front of the carrier.

According to Mr. Siemens' new method, a complete circuit is formed by the current of transmission, with which several stations may be brought into communication with each other. The transmitting and receiving apparatus is extremely simple, and consists of two short pieces of tubing the same diameter as the main tube, and out of the latter a piece is removed of equal length. By means of a crank, or rocking shaft movement, either of these short tube pieces may be connected with the main tube by a simple movement of a lever, and thus brought into circuit. One of these short tubes is open throughout. This is the transmitter. It is ordinarily kept in circuit, so that messages to other stations beyond may pass through. When it is desired to send a message, the circuit is broken by moving the transmitter a little to one side ; the carrier with its message is then placed inside, and after communicating by signal with the station for which it is intended, the transmitting tube is once more brought into circuit, when the current of air immediately catches the carrier and hurries it on to its destination. Upon receipt of the signal at the further station for which the message is intended, the person in charge brings the receiver into circuit. This consists of a tube similar to the transmitter, with the exception that it is partially closed at one end so as to catch the carrier as it arrives. Its arrival is ascertained by the click caused by its striking the partially closed end of the receiver, which is then drawn back to extract the carrier, and the open transmitter is at the same time thrown into circuit so as to allow any through messages to pass. As each through message passes a station it causes a small bell to ring, as a signal to the superintendent, and to enable him to count when any message is due for his station. By this means a continual service of messages may be carried on in any circuit, the amount of business transacted being limited only by the means of the superintendents at each station to keep pace with the arrival and despatch of messages.

MARINE ENGINES IN THE BRITISH NAVY.

From "The Engineer."

So long as our ships of war were provided with masts and sails, the failure of their engines might be looked upon as a matter of second-rate importance. The Warrior, Bellerophon, and other ships of what may now be regarded as an old type, enjoyed peculiar advantages in this respect. In the mercantile marine we seldom or never meet with ships at once full powered and full masted. Either the engines are everything and the sail power of the ship little or nothing, or the masts and sails are regarded as the essential means of propulsion, the engines being merely auxiliaries to be used with discretion in calms and light winds. A break-down in the engine-room of a full powered Atlantic steamer leaves her practically useless for the time being, though not quite helpless. The failure of auxiliary engines, on the other hand, can do little more harm than is represented by the duration of a given voyage being possibly prolonged by a few days. Our first steam war ships, however, were not only full masted but full powered, and if one means of progression failed, the other was always available. But our new men-of-war of the type represented by the Glatton and Devastation are absolutely dependent on their engines and on their engines alone. A Cunard steamer breaking a paddle shaft in the middle of the Atlantic could still manage to get to a port, because she could show something like a fair spread of sail; but ships of the Glatton type would become helpless logs upon the water if their machinery gave way. In a word, not only the efficiency, but the very safety of the ship and crew absolutely depends on the integrity of the engines by which they ought to be propelled. It has frequently been argued for this very reason that the construction of mastless ships was a great mistake; but, in reply, it has always been urged that so long as machinery was carefully protected from shot, the chance of a break down was too slight to deserve attention. This argument was good as far as it went, but men must be blind to passing events if they are content to accept it any longer. Unfortunately the breaking down of marine engines in the navy appears to be becoming the rule instead of the exception. We have recently called attention to the repeated splitting and cracking of the great cylinders of our largest iron-clads, and as if to confirm the accuracy of our statements, and to lend force to our arguments, the news comes to us this week that the Swiftsure —a very recent addition to our navy— cracked both her cylinders on her first run from Jarrow to Keyham. This is bad enough, but it is not all. The cylinders were patched, and it was believed that no further failure need be feared; but the belief was unfounded, and, as we report in another column, the cylinders have again given way and are to be patched again. There is an old sea-phrase about "patch upon patch, like a sand barge's mainsail." The new version will run "patch upon patch, like an iron-clad's cylinder." Patching a mainsail is all very well for the owners of sand barges, but we cannot look upon the presence of patched cylinders in our unmasted navy with anything like contentment. And yet the marine engineers are in this dilemma:—If they take out a pair of cracked cylinders and replace them with others precisely the same, as like causes produce like effects, it is certain that the new cylinders will quickly follow those which they replaced to the scrap heap. If, on the contrary, a different design is adopted in the new cylinders, then the makers tacitly admit that they made a mistake in designing the first cylinders, and so far they imperil their reputation; and besides, it must be remembered that the new cylinders may not be a bit more durable than their predecessors. However, whether a reputation does or does not suffer, it is clear that we cannot go on making our cylinders in the old way. There is not a pin to choose among the firms who supply our men-of-war with engines. No matter where the cylinders come from, they split, and it is evident that the cause of these repeated failures must be investigated and dealt with on scientific principles. No rule-of-thumb scheming, no putting a bit more metal here and a bit less there, as best suits the fancy of the designer, will overcome the difficulty. We must first learn all about it; and this done, it is certain that there is sufficient talent and skill available among our marine engineers to enable them either to elude the difficulty or to beat it by main force.

There is not a firm of marine engineers in this country who could not legitimately plead want of experience as their excuse for the failures. The particular kind of break-down under consideration is confined almost altogether to engines of the largest size. Of these engines really very few have been built; and it is just as well that this fact should be made to assume its proper importance. It is almost true that the largest cylinders in existence are to be found in the navy; and it is quite true that the largest horizontal engines ever built propel our war ships. The cylinders of the Hercules, for example, are 127 in. in diameter, 4 ft. 6 in. stroke. A few figures about cylinders will not be altogether out of place. The Persia had cylinders 100 in. in diameter, with a piston stroke of 10 ft. The Arabia had 103 in. cylinders, 9 ft. stroke. The Golden City—Pacific mail—had a single cylinder 105 in. diameter and 12 ft. stroke. We could, if it were necessary, easily give a long list of enormous cylinders; but it will not be disputed that engines with cylinders 120 in. in diameter are extremely rare. It is quite true, nevertheless, that as far as mere weight of metal goes, heavier cylinders than any to be met with in our navy have been successfully used for years, *but they were always fixed in a vertical position.* Engineers are, in a word, only learning now of what the horizontal type is and is not capable; and as not more than a dozen horizontal engines of the dimensions thereabouts of those in the Hercules, for example, have ever been made or used, it is certain that engineers must lack experience in the construction of such colossal machines.

It will be seen that we have placed particular stress on the horizontal position of the cylinders, and this we do because we believe that to it, and to it alone, the whole of the mischief is due. It remains to be seen whether the obstacles which exist to the use of very large horizontal cylinders can or cannot be got over; but meanwhile we have the broad fact to go upon, that whereas cylinders larger in one sense and heavier than those in use in the navy have been worked for years without failure, we find other cylinders with very much in common with the successful ones, splitting almost the moment they are put to work on their sides. Is it too much to assume that, if the cylinders of the Persia had been bolted down in a horizontal position on a rigid framework, they would have split?

We have said that it is essential to success in any attempt to get over the difficulty, that the causes of the failure should be carefully investigated, and this assertion requires a word of explanation. We assume that the most obvious cause of fracture is the position of the cylinders on their sides, and this we do simply because, as we have been at some pains to show, vertical cylinders as heavy do not break. But the horizontal position will not alone explain the causes of failure. It is only one condition of failure, one link in a chain. The reason why large horizontal cylinders split must be sought in the unequal strains set up in a great body of metal irregularly shaped by contraction and expansion. From the way in which these cylinders are fixed, the top side is always more free to expand than the bottom side, and, as a consequence, the cylinder tends to assume the form of an arch, and this will bring an enormous strain on the metal. It must not be supposed that the cylinders always crack longitudinally; on the contrary, the crack may run in any direction, usually taking its rise near the corner of a port. It is a complete mistake, again, to imagine that the cylinder is uniformly of the same temperature throughout; on the contrary, every portion of it changes its heat more or less throughout the progress of each stroke. As an illustration of our meaning, we may cite the case of Cornish engine cylinders. As they are single-acting, the top of the cylinder is always hotter than the bottom, and it is therefore the practice to bore large cylinders as much as $\frac{3}{16}$ in. smaller at the top than the bottom, so that the cylinder may be all of the same size when under steam. In the same way the cylinder of a double acting expansive engine is, no doubt, larger at each end than in the middle, on the average; but it is equally certain that it is in continual motion, expanding and contracting at each end with each stroke of the engine, while the central portion remains pretty much of the same size. Large horizontal cylinders are virtually so weak that they must be bored in a horizontal position if they are to be true. And when we tie down what are virtually huge rings of cast iron with heavy excrescences on them, to a massive framing, a prediction that they will break when heated is in strict accordance with the laws of science. The chance of failure is, beyond question, increased by the use of hard metal. It is, of course, desirable that a cylinder face should be as hard as possible; but it is not an easy task to combine hardness and toughness in the same cylinder.

More than one radical cure for the evil fortunately suggests itself. In the first place, as we have already pointed out, the best plan will be to use more cylinders than two, and so keep them of reasonable dimensions. Whether this plan is or is not adopted, a very radical change must be introduced in the design of framing, the cylinders being only secured at one end, and *supported*, but not fixed at the other. To carry out this arrangement effectually will require no small amount of talent and skill on the part of the designer. The most radical remedy of all would be the resort to vertical cylinders, and there is much less to be urged against this than may appear at first sight. In our earlier steam frigates it was essential that the machinery should be kept below the water line, to secure immunity from the guns of an enemy, but this consideration is of no weight in the case of iron-clad ships. Nothing, indeed, would be more easy than to provide, even in an otherwise unarmored ship, the most efficient protection for such of the machinery as might chance to stand 20 ft. above the keel, in the shape of a few armor plates, disposed box battery fashion on the main deck.

EXPERIMENTAL STEAM BOILER EXPLOSIONS.

By Professor R. H. Thurston.

From "The Journal of the Franklin Institute."

The public, quite as much as professional engineers, have, from the earliest period in the history of the application of steam to useful purposes, felt a perfectly justifiable distrust of the steam boiler, whatever its form.

Indeed, the greater our familiarity with that powerful instrument, the more thoroughly do we appreciate the danger which attends its use, and those of the profession who have ever had charge of the machinery of a steam vessel, need not be reminded of the unceasing sense of anxiety and responsibility that, in most cases, has probably oppressed them by day and by night, when steaming, even where they have felt the greatest confidence in the intelligence and zeal of those to whom they have intrusted the care of the boilers.

Such terrible disasters as that which occurred on the Westfield last summer, and the epidemic of explosions that have signalized the last few months, have thoroughly re-awakened and intensified the apprehensions so universally felt.

It is to be hoped that a useful result may be a more earnest and intelligent investigation of the subject, and such additional legislation as may make the system of governmental inspection far more efficient than it is at present in the prevention of dangerous explosions.

During a few years past a number of accomplished engineers have been called, by the character of their duties, to investigate the circumstances attending nearly every case of steam boiler explosion in Great Britain, and recently many cases in the United States have been examined with similar care and skill.

A committee of the most experienced and talented among British engineers has also recently given attention to the same subject, with the object of determining what legislation should be recommended, and how far legislation may be expected to remedy this apparently rapidly increasing cause of danger to the public.

The very considerable amount of information thus obtained has been extremely useful in dispelling many of the strange superstitions and extraordinary theories, of which both ignorance and intelligent but misdirected ingenuity have been wonderfully prolific. The conclusion which has been arrived at, after the examination of many hundreds of cases of accidental steam boiler explosion, is that such so called accidents are the result of neglect or ignorance, and are never to be attributed to causes which are not, or may not be, easily understood by persons of ordinary intelligence. It is believed that most of these causes are now understood, that they are few in number and are readily controlled by the exercise of intelligence and vigilance.

A *direct proof* of these deductions is, however, still needed, and this can only be obtained by a series of experiments made with direct reference to the production of such proof. Such experiments would be the exploding of boilers under, as nearly as possible, the conditions observed in practice and carefully studying the influence that variations of those conditions may have upon the nature and intensity of the resulting effects.

Comparatively little has yet been done in this direction. More than thirty-five years ago, a committee of the Franklin Institute made a series of experiments of such extent and accuracy that the republication of their reports, and their circulation among engineers, would to-day be a public benefaction.* Their reports, together with the paper of F. A. Paget, on the "Wear and Tear of Steam Boilers,"† and the little book of E. B. Martin‡ on explosions, should be in the library of every engineer.

The experiments of the committee of the Franklin Institute were made upon a small scale, and upon constructions quite different in form from most steam boilers, and, although the information obtained was invaluable, it still remained desirable to repeat their experiments and to make other investigations with boilers of full size, such as are used in steamers,

* Vide Journal Franklin Institute, 1836, Vol. XVII.

† Ibid., 1865 Vol. I.

‡ Records of Steam Boiler Explosions; E. B. Martin. London: E. & F. N. Spon, 1871.

on our railroads, and in our manufactories. The only experiments of this kind ever attempted were probably those referred to by the President of the Franklin Institute, in his letter published in the concluding number of the last volume of this Journal.

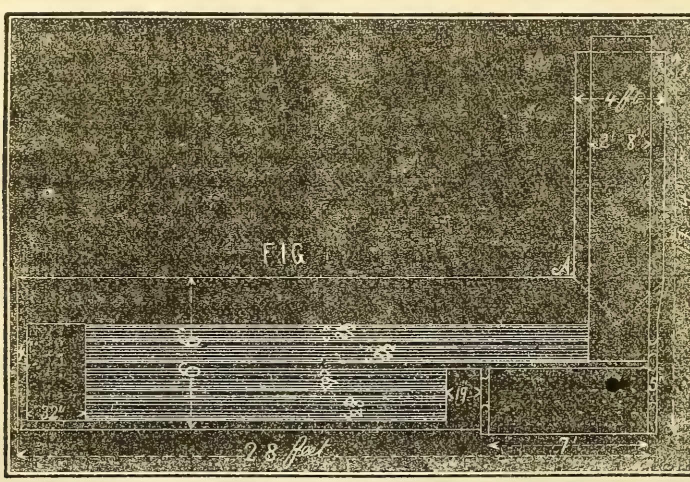
It was intended to defer an account of their orgin and progress until the completion of the series, but as cold weather has interrupted operations, and as the work will not be resumed until spring, it is considered advisable to describe the experiments already made.

These experiments were projected and conducted by Mr. Francis B. Stevens, of Hoboken. They were planned several months ago, and at the request of Mr. S. the United Railroad Companies of New Jersey, with an intelligent appreciation of the importance of such an investigation, both to themselves and to the public, appropriated the sum of ten thousand dollars to enable Mr. Stevens to enter upon a preliminary series of experiments. They, at the same time invited other railroads and owners of steam boilers to co-operate with them, and offered the use of their shops for any work that might be considered necessary or desirable during the progress of the work.

Several old boilers had recently been taken out of the steamers of the United Companies. These were subjected to hydrostatic pressure, until rupture occurred, were repaired and again ruptured several times each, thus detecting and strengthening their weakest spots, and finally leaving them much stronger than when taken from the boats. The points at which fracture occurred and the character of the break were noted carefully at each trial.

After the weak spots had thus been felt out and strengthened, the boilers were taken, with the permission of the War Department, to the U. S. reservation at Sandy Hook, at the entrance to New York Harbor, and were there set up in a large enclosure which had been prepared to receive them. This work was one of great difficulty, but it was skilfully performed, and was accomplished without accident, and the 4 old steamboat boilers above referred to, together with 5 new boilers built for the occasion, were placed in their respective positions without having been in any way injured.

Finally on the 22d and 23d of November, the experiments to be described were made. A large party of gentlemen, many of whom were professional engineers, and all of whom were deeply interested in the subject, were invited to attend by Mr. S., on behalf of the United Railroad Companies of New Jersey.



The first boiler attacked was an ordinary "single return flue boiler." Fig. 1.

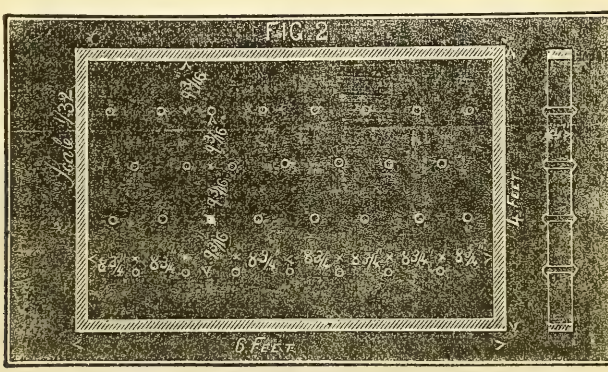
The cylindrical portion of the shell was 6 ft. 6 in. diameter, 20 ft. 4 in. long, and of iron a full $\frac{1}{4}$ in. thick. The total length of the boiler was 28 ft., the steam chimney, was 4 ft. diameter, $10\frac{1}{2}$ ft. high, and its flue was 32 in. diameter. The 2 furnaces were 7 ft. long, with flat arches. There were 10 lower flues, 2 of 16 and 8 of 9 in. diameter, and all were 15 ft. 9 in. long; there were 12 upper flues, 8½ in. in diameter, and 22 ft. long. The total grate surface was 38½ sq. ft.; heating surface 1,350 sq. ft. The water spaces were 4 in. wide, and the flat surfaces were stayed by screw stay-bolts at intervals of 7 in.

This boiler was one of a pair built by Fletcher, Harrison & Co., of New York, for the steamer Joseph Belknap, in 1858, and, with its fellow, which was also on the ground, had seen 13 years of service. The last Inspector's certificate had allowed 40 lbs. of steam. The upper portion of the boiler, when inspected before the experiment, seemed to be in good order. The girth seams on the under side of the cylindrical portion had given way, and had all been patched before it was taken out of the boat. The water legs had been considerably corroded.

In September last, in presence of several gentlemen who had been invited to witness the test, this boiler had been subjected to hydrostatic pressure, giving way by the pulling through of stay-bolts at 66 lbs. per sq. in. It was repaired, and, afterward, at Sandy Hook, was tested without fracture to 82 lbs., and still later bore a steam pressure of 60 lbs. per sq. in.

On its final trial, November 22d, a heavy wood fire was built in the furnaces, the water standing 12 in. deep over the flues, and, when steam began to rise above 50 lbs., the whole party retired to the gauges, which were placed about 250 ft. from the enclosure, and which had been there proved to give accurate indications. The notes of pressures and times were taken as follows:

Time.	Pressure.
2.00 P. M.	58 lbs.
2.05 "	68 "
2.10 "	78 "
2.15 "	87 "
2.20 "	91½ "
2.23 "	93 "
2.25 "	91½ "
2.30 "	91 "
2.35 "	91½ "
2.40 "	91½ "
2.45 "	91 "
2.50 "	90 "



The pressure rose rapidly until it reached about 90 lbs.,* when leaks began to appear in all parts of the boiler, and at 93 lbs. a rent at (A, Fig. 1) the lower part of the steam chimney where it joins the shell becoming quite considerable, and other leaks of less extent enlarging, the steam passed off more rapidly than it was formed. The pressure then slowly diminishing, the workmen extinguished the fires by throwing earth upon them, and the experiment thus ended.

The second experiment was made with a small boiler (Fig. 2), which had been constructed to determine the probable strength of the stayed surface of the Westfield's boiler. It had the form of a square box, 6 ft. long, 4 ft. high, and 4 in. thick. Its sides were $\frac{5}{16}$ in. thick, of the Abbott Iron Company's "best flange fire-box" iron. The water space was 3⅝ in. wide. The rivets along the edges were ¾ in. diameter, spaced 2 in. apart. The two sides were held together by screw stay-bolts, spaced 8¾ and $9\frac{3}{16}$ in., and their ends were slightly riveted over, precisely copying the distribution and workmanship of that water leg of the Westfield, which was formed between the back connection and the back end of the boiler. It had been tested to 138 lbs.

* The ultimate strength of this boiler, when new, was probably equal to about double this pressure.

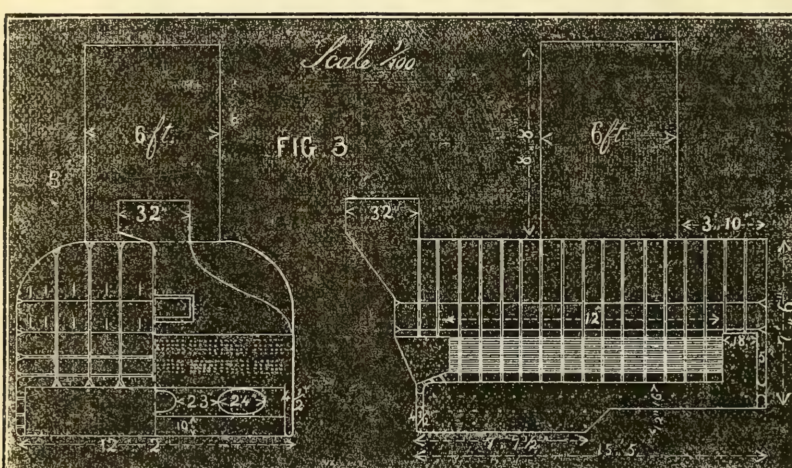
pressure. This slab was set in brickwork, about $\frac{5}{6}$ths of its capacity occupied by water, and fires built on both sides. Pressure rose as shown by the following extract from the note-book of the writer:

Time.	Pressure.
3.18 P. M.	0 lbs.
3.20 "	4 "
3.21 "	5 "
3.22 "	7 "
3.23 "	9 "
3.24 "	11 "
3.25 "	13 "
3.26 "	15 "
3.27 "	18 "
3.28 "	20 "
3.29 "	23 "
3.30 "	27 "
3.31 "	30 "
3.32 "	34 "
3.33 "	38 "
3.34 "	44 "
3.35 "	49 "
3.36 "	51 "
3.37 "	54 "
3.38 "	58 "
3.39 "	65 "
3.40 "	72 "
3.41 "	78 "
3.42 "	86 "
3.43 "	94 "
3.44 "	100 "
3.45 "	110 "
3.46 "	117 "
3.47 "	126 "
3.48 "	135 "
3.49 "	147 "
3.50 "	160 "
3.51 "	165 "
	Exploded.

At a pressure of slightly above 165, and probably at about 167 lbs., a violent explosion took place. The brickwork of the furnace was thrown in every direction, a portion of it rising high in the air and falling among the spectators near the gauges; the sides of the exploded vessel were thrown in opposite directions with immense force, one of them tearing down the high fence at one side of the enclosure, and falling at a considerable distance away in the adjacent field; the other part struck one of the large boilers near it, cutting a large hole, and thence glanced off, falling a short distance beyond.

Both sides were stretched very considerably, assuming a dished form of 8 or 9 in. depth, and all of the stay-bolts drew out of the sheets without fracture and without even stripping the thread of either the external or the internal screw; this effect was due partly the great extension of the metal, which enlarged the holes, and partly to a rolling out of the metal as the bolts drew from their sockets in the sheet.

Lines of uniform extension seem to be indicated by a peculiar set of curved lines cutting the surface scale of oxide on the inner surface of each sheet, and resembling



closely the lines of magnetic force called, by physicists, magnetic spectra. These curious markings surrounded all of the stay-bolt holes.

The third experiment took place on the 23d of November. The boiler selected on this occasion is shown in Figure 3. It was a "return tubular boiler," with no lower flues; the furnace and combustion chamber occupying the whole lower part. Its surface extended the whole width of the boiler, thus giving an immense crown sheet, which was perfectly flat, and was braced to the shell by "crow-foot" braces whose rods were in section 2 in. by ½ in., and spaced 12 in. lengthwise and 17 in. crosswise the boiler; each brace sustained an area of 204 sq. in. The water legs were secured by stay-bolts of 1 in. diameter, spaced 12 in. by 8. The horizontal braces were spaced 28 in. by 12, and were 1⅓ in. diameter. The shell was of No. 3 iron, single riveted. There were 384 tubes, 2 in. diameter and 12 ft. long. The steam drum was placed at the middle of the boiler, and was 6 ft. diameter, and 8 ft. 8 in. high.

This boiler was built in 1845, by T. F. Secor & Co , and had been at work *twenty-five years;* when taken out, the inspector's certificate allowed 30 lbs. of steam. In September it was subjected to hydrostatic pressure, which at 42 lbs. broke a brace in the crown sheet, and at 60 lbs , 12 of the braces over the furnace gave way, and allowed so free an escape of water as to prevent the attainment of a higher pressure. The broken parts were carefully repaired, and the boiler again tested at Sandy Hook at 59 lbs., which was borne without injury, and afterward a steam pressure of 45 lbs. left it still uninjured. At the final experiment, the water level was raised to the height of 15 in. above the tubes, and it there remained to the end. The fire was built, as in the previous experiments, with as much wood as would burn freely in the furnace, and the record of pressures was as follows:

Time.	Pressure.
12.21 P. M.	29½ lbs.
12.23 "	33½ "
12.25 "	37½ "
12 27 "	41 "
12.29 "	44½ "
12 31 "	48½ "
12.32 "	50 " brace broke.
12 33 "	52 "
12.34 "	53½ " exploded.

When a pressure was reached of 50 lbs. per sq. in., a report was heard, which was probably caused by the breaking of one or more braces, and at 53½ lbs., the boiler was seen to explode with terrible force. The whole of the enclosure was obscured by the vast masses of steam liberated; the air was dotted with the flying fragments, the largest of which—the steam drum—rising first to a height variously estimated at from 200 to 400 ft., fell at a distance of about 450 ft. from its original position. The sound of the explosion resembled the report of a heavy cannon. The boiler was torn into many pieces, and comparatively few fell back upon their original position.

The same bulging of stay-bolted surfaces that was noticed in the preceding experiment was observed here, and the screw stay-bolts slipped out as before, without breaking and without stripping their threads. The braces were usually broken at the welds.

Having briefly described these experiments, it may be well to notice what bearing their results have upon existing beliefs, and how far they extend our knowledge of the causes and conditions of explosions.

In the first experiment, we probably have an illustration of by far the most usual behavior of steam boilers, when yielding to over-pressure. The pressure gradually rising, ruptured the boiler at its weakest point, which happened to be a spot of merely *local* weakness; the rent extended toward stronger portions, but soon became large enough to discharge the steam as rapidly as it was made. The strength of the metal in the direction of the line of fracture being sufficient to resist further extension at the maximum pressure attained, no greater injury was done. The spot being patched, the boiler is probably still capable of doing good service for a considerable length of time.

When boilers give way from excessive weakness or from over pressure, they very generally do so in the manner described. The explosion is the exceptional case, and the frequency with which old boilers "blow out" in every part, though usually about the stayed surfaces, and the apparent impunity with which they are kept at work after being frequently patched, has probably been the most influential cause of the existence of the belief, which is, unfortunately, widespread among engineers, that the mere pressure of steam cannot cause explosions. and that, if the boiler contains a sufficient quantity of water, it is perfectly safe, except against sundry mysterious forces, which are probably, like the fairies and ghouls of earlier times, existent only in the imaginations of those whom they terrify.

In the second and third experiments, we have illustrations of the comparatively rare cases in which explosions actually occur.

The second was a perfectly new construction, in which corrosion had not developed a point of great comparative weakness, and the edges yielding along the lines of riveting on all sides simultaneously and very equally, the two halves were completely separated, and thrown far apart with all of the energy of unmistakable explosion, although there was an ample supply of water, and the pressure did not exceed that frequently reached in locomotives and on the Western rivers, and although the boiler itself was quite diminutive.

The circumstance of the drawing out of the stay-bolts without breaking and without stripping their threads, was one of the most interesting points of the experiment.

Constructing a formula upon the very probable hypothesis that this was an example of average American practice, we obtain for ordinary use $d = \frac{365\,t}{\sqrt{f\,P}}$; where d = the distance between the stay-bolts, t = the thickness of the plates, P = the pressure and f = the factor of safety, which certainly *ought in no case to be less than six.*

Also $P = f\left(\frac{365\,t}{d}\right)^2$, the units of measure being lbs. and inches.

Fairbairn proved, by experiment, that the diameter of screwed stays should be double the thickness of the sheet, in order to make their tensile strength equal to the force that would draw them out of the sheets. To this should be added $\frac{1}{4}$ in. allowance for corrosion. These stay-bolts should have been $\frac{7}{8}$ in. in diameter, the $\frac{1}{4}$ in. excess of diameter being comparatively valueless.

The spacing of the stay-bolts in a boiler of such workmanship, intended to carry 40 lbs. of steam, and taking six a sa factor of safety, should, however, have been $d =$

$$\frac{365 \times \frac{5}{16}}{\sqrt{6 \times 40}} = 7.3 +,$$

or about $7\frac{1}{2}$ inches.

Fairbairn showed that properly riveting over the ends, increased the strength of stay-bolts 14 *per cent.*

In the third experiment, as in the second, it is probable that the weakest part extended very uniformly over a large part of the boiler, either in lines of weakened metal, or over surfaces largely acted upon by corrosion. Immediately upon the giving way of its braces, fracture took place at once in many different parts.

In this example, the boiler had been standing a week with steam up, but with none blowing off, and feed being pumped in, unless to supply the insignificant waste from leakage. It was set on solid ground, and the water which it contained could not have been in the slightest degree agitated. It has been a question whether the water might not, under these circumstances, have become super-heated, as in the cases first noticed by M. Deluc, and since investigated by MM. Downy, Dufour and others, and whether the violence of this explosion may not have been largely due to such action.

When it is remembered, however, that those experimenters found it difficult to induce this condition in metal vessels with even minute quantities of water, and that the extent of this super-heating becomes quite small with very small quantities of the fluid, growing rapidly less as the bulk of water increases, it may be very much doubted whether it would be possible to obtain such a state in this case, where tons of water were contained in a rough metal vessel, and also where a circulation was constantly kept up by a fire at one end.

The quantity of heat thus stored up must have been very small, even if there were any such excess.

Were it known precisely to what height the steam drum, for example, was thrown in this case, it would be easy to determine with great certainty, whether the steam released at $53\frac{1}{2}$ lbs. pressure was sufficient to produce the effects noted.

We have made such an estimate, but the data are too unreliable to admit of its publication, although it confirms our opinion that no super-heating of the water in the boiler took place.

We may conclude, then, from the result of Mr. Stevens' experiments:—

First, That "low water," although undoubtedly one cause, is not the only cause of violent explosions, as is so commonly supposed, but that a most violent explosion may occur with a boiler well supplied with water.

This was shown on a small scale by the experiments of the committee of the Franklin Institute above referred to.

Second, That what is generally considered a moderate steam pressure may produce the very violent explosion of a weak boiler, containing a large body of water, and having all its flues well covered.

This has never before, we believe, been directly proven by experiment.

Third, That a steam boiler may explode, under steam, at a pressure less than that which it had successfully withstood at the hydrostatic test.

The last boiler had been tested to 59 lbs., and afterward exploded at 53½ lbs. This fact, too, although frequently urged by some engineers, was generally disbelieved. It has now been directly proven.*

There can now be no excuse for the implicit confidence so generally felt in the use of the hydrostatic test, or for not at least combining with it, in every inspection, the use of the "hammer test" by experienced inspectors.

It may be finally remarked, that welded boiler braces, and screw stay-bolts which have not nuts at their end or are not well riveted over, should evidently be distrusted.

This extremely interesting and important series of experiments will be continued on the return of warm weather, and it is hoped that Congress may be induced to make provision for its extension. A very excellent report, made to the Secretary of the Navy, by Chief Engineers Isherwood, De Luce and S. Albert, has been printed by Mr. Stevens, together with a memorial, asking Congress to take action in this matter, which is of such great importance to the public.

These will be circulated among those who may be willing and able to aid in the plan proposed.

It is proposed by Mr. Stevens in the experiments succeding those now prepared, to determine the conditions, of explosion with low water, to examine into the effect of opening the safety valve suddenly upon an already heavily strained boiler, and to check those experiments that seem to prove explosions to occur from excessive pressure, by leading steam at high pressure into a comparatively weak boiler containing no water. It is intended to explore this wide field of research as thoroughly as available time and money will allow.

It is to be hoped that our wealthy railroad corporations, and owners of steam vessels, may see how deeply their own interests are involved in the prosecution of such researches, and that they, as well as the General Government, may assist in continuing these investigations.

* A number of instances of this kind, though not always producing an explosion, have been made known to the writer.

Two boilers at the Detroit Water Works, in 1859, after resisting the hydrostatic test of 200 lbs. with water at a temperature of 100 deg. Fahr., broke several braces each at 110 and 115 lbs. steam pressure respectively, when first tried under steam.

The boiler of the U. S. steamer Algonguin was tested with 150 lbs. cold water pressure, and broke a brace at 100 lbs. when tried with steam.

A similar case occurred in New York, a few years ago, and the boiler exploded with fatal results.

These accidents are probably caused by changes of form of the boiler, under varying temperature, which throw undue strain upon some one part, which may have already been nearly fractured.

THE WAR DEPARTMENT REPORT ON GUN-COTTON.

From "The Engineer."

Public opinion, bearing upon the majority of manufactures, displays its wisdom in keeping steadily in view, as a purpose to be achieved, the rendering of manufactures harmless to those engaged in them. Mostly this can be done, or a point of perfection arrived at corresponding to nearly done. But some manufactures may be cited to which the observation does not apply, manufactures wholly exceptional, the conduct of which can neither be brought within absolute safety to those engaged, nor, as an alternative, abandoned, seeing that the result of many such manufactures represents an improvement. Gunpowder is in this category, and, in a way still more pronounced, a long list of chemical explosives, some too violent for the best control, others, though terrible, still less violent, and, under certain risks, to be calculated and dared, utilizable. Despite the best precautions observed, or capable of being observed, gunpowder mills and storages blow up from time to time; in like manner mercury fulminate factories, not to speak of dynamite, nitro-glycerine, and its congener, known as lithrofacteur. Nobody ever proposes abandonment of the manufacture of gun-cotton or mercury fulminate on hearing of an accident; in Germany both dynamite and nitro-glycerine are made both on the large scale, without the Government—so stringent when deemed needful—having seen fit to put the manufacture down. But when in the late summer of last year an explosion of gun-cotton occurred at Stowmarket, a section of the public, scared and excited, raised clamors for the Government to step in, preventing the manufacture of gun-cotton in bulk in this country at all. And on what ground? Because of the terrible nature of the substance, and the accident, said the public; because of the large number of killed and wounded; because gun-cotton when made and stored is known to explode spontaneously sometimes, and when not exploding spontaneously is known not to keep without deterioration, or it may be utter spoliation. As to the two first reasons, they positively have no weight at all as an indictment against the commercial manufacture of gun-cotton. Like other explosives, the preparation of it on the large scale, is obviously incompatible with the manufacturer arriving at that point of absolute safety which philanthropy would desire. To be an explosive means being a source of instantaneous danger; for dependent on the instantaneous elimination of force is the pure projectile function. The substance is terrible, is known and meant to be terrible. An explosion of it occurring in proximity to human beings must well-nigh of necessity prove destructive to human life. But the third and fourth allegations, namely, that gun-cotton had been known to explode spontaneously, and that it could not be kept unchanged over a practically short space of time—these allegations, once satisfactorily made out, would, or at least should, have led to the abandonment of the gun-cotton manufacture. With respect to so-called spontaneous explosion, we have already maintained in these columns that the phrase, though very usual, is self-contradictory. Until the recognition is granted of an effect without cause, there can be no such thing as spontaneous explosion or combustion. All that the word "spontaneous" really in this application of it can be held to signify is the happening of a result determined by an hitherto occult cause. Practically, however, it matters not. Were it demonstrated or demonstrable that gun-cotton was explodable under the influence of conditions unknown, or, if known, irremediable, then, for this reason alone, the manufacture of it should be abandoned, on the very sufficient ground of being unfitted to fulfil the purpose for which its manufacture was carried on. If, again, demonstration should be made that gun-cotton could not be preserved without change over a competent space of time within the bounds of practical need, then, likewise, its manufacture would have been useless. A thing so circumstanced would have been totally unfitted for all ends required of an engineering explosive. Happily a Government Commission of Inquiry has been issued, and is satisfactory. Dealing with the two allegations, it has disposed of them in the negative, and, consequently, in a sense favorable to the resumed manufacture and engineering employment of gun-cotton. "The Committee, after a careful review of the documents in their possession, and of the evidence of the officers above mentioned and others, respecting the use and application of compressed gun-cotton, principally as regards its employment for military purposes, consider that its use is not only unattended by either uncertainty or peril, but that the material as an explosive agent is effective, certain, safe, portable, and easy in employment. The Committee therefore feel that they are warranted in the expression of a strong opinion of its great value for military engineering purposes generally, and for submarine mining. The Committee therefore feel no hesitation in recording their opinion that there is no reason why the War Department should relinquish the manufacture of compressed gun-cotton. The only part of the manufacture of gun-cotton to which danger attaches is the drying. Up to that stage the material contains from 15 per cent. to 20 per cent. of water; but the Committee express an opinion that the operation as carried on at Stowmarket is open to objection, and that no difficulty will be experienced in devising a safe and simple method of drying, which may be easily applicable to any locality." One of the most valuable points comprised in the Government preliminary report, is concerning the durability of gun-cotton when manufactured and stored. The War Department has in its possession specimens of gun-cotton 9 years old, and still as good as ever. Now 9 years is, practically considered, a long time—quite long enough to warrant continuance in the use of a material the engineering utility of which, in its unchanged state, is no l onger a question. Nothing in the evidence tendered goes to show that the gun-cotton already 9 years stored might not remain uninjured 90 or even 900, which is much more than can be averred of gunpowder, a material far from indestructible when quite dry, and rapidly destructible when moistened ; whereas gun-cotton may not only be flooded with water without disadvantage, but with absolute immunity from change, so far as experience has gone.

In expressing satisfaction that the War Department has seen fit to make this useful investigation, and that the issue of it is so reassuring, we only echo the testimony of all who have experienced the power of gun-cotton for its own legitimate use, when we say it would have been a subject of deep regret had the manufacture of this agent been summarily abandoned in deference to unreasoning public clamor. Considered as a projectile agent for gun charges, ordnance, or small arms, we believe gun-cotton to be practically useless, and this is asserted under full acquaintance with the fact that a gun-cotton battery of field pieces was set on foot under the auspices of Baron Lenk, he who introduced the substance to Messrs. Prentice, at Stowmarket, and induced the commencement of the factory which blew up last year. Whether as a charge for artillery or small-arms, gun-cotton has invariably proved too immediately shattering for the due exercise of propulsive force, combined with safety to the gun. But the time, if it has not yet come, is near at hand when naval ordnance at least are to be of less account than formerly. Obviously, to common apprehension, the most promising way to demolish a floating structure is to hit her somewhere below the line of floatation. Ordinary artillery cannot effect this. Submarine artillery may do so, but, all evidence taken into account, a propulsive torpedo would accomplish this result better. Now, the requisite for the best torpedo explosive is not the same as for an ordinary fire-arm propulsive, where extreme shattering power is, as already stated, a defect. For a torpedo charge, the more immediately shattering an explosive is, the more *vis viva* it has, by so much is it better to promote the end desired. Of course the use of it must be brought within the limits of safety, or else it could not be employed. Gun-cotton is demonstrated to be within those limits, and so far as we know, only gun-cotton. Chloride of nitrogen would be wholly unmanageable, and, as for nitro-glycerine, it is only just one shade more practicable. In the interest of our future torpedo service, then, we say it is fortunate that the War Department Commission on the practicablity of gun-cotton has been instituted, has delivered its preliminary report, and that the report is so reassuring.

PRESERVATION OF WOOD FROM DECAY.

By HERMAN HAUPT, C. E.

Written for Van Nostrand's Magazine.

On the occasion of the proposed formation of a Company in Philadelphia for the construction of wood pavements, the writer was requested to examine and report upon the various processes employed as proposed, for the treatment of wood as a protection against decay. Considerable time was spent in this investigation, and various experiments were made, the results of which may possibly be of some interest and value to the engineering profession. Facts are generally important, and failures often indicate the road to success. The report in the processes examined was unfavorable ; the Company did not go into operation, and the results of the experiments and inquiries are not generally known. The report was suppressed, as facts were reported impartially, without regard to their effect upon private interests.

No other apology will be offered for this communication, which will include portions of the report referred to. It is believed that although all previous attempts to preserve wood by processes at the same time effective and economical, including the experiments of the writer himself, have been failures, it is not impossible to accomplish an object so desirable, and an effort will be made to indicate the conditions essential to success.

To present in an intelligible manner the processes used and results obtained in the treatment of wood, to expose the defects of existing modes of operation, and to lead to suggestions of improvement, it is neccessary to enumerate some of the principal agents and materials employed in such processes and define their properties.

WOOD.

Wood contains about 4 per cent. of soluble and 96 per cent. of fibrous material. It forms a hard porous tissue, the size and number of the pores varying with the kind of wood. The fibrous portions of all woods are heavier than water, and have a specific gravity about equal to the fibre of flax, or 1.5. The fibres are not continuous throughout the stick, but are short and overlap, arranged in echelon. Wood floats in water consequently by virtue of the air confined in the cells. When completely saturated with water, all woods must sink. Dried at 86 deg. Fahrenheit, 1 lb. troy of wood yields, by distillation, 7 oz. wood acid, $1\frac{1}{4}$ oz. combustible oil, and $3\frac{3}{4}$ oz. charcoal. The variation in different woods is not very great.

Experiments were made by Mr. Merrill, at South Boston, to determine the quantity of coal oil absorbed by wood. Pieces of green birch were boiled in oil. when the temperature rose above 212 deg., bubbles escaped in great numbers from the ends of the sticks, and in small quantities also from the sides, showing that the expulsion of water did not proceed from the ends only. At 300 deg. the bubbles ceased. Upon removing from the fire, the wood, which had floated on the surface of the oil, sank to the bottom. The specific gravity of the oil was 1.025 deg.

A second experiment was made, after carefully drying the wood, at a temperature of 286 deg., to expel all free moisture. When boiled in the oil, bubbles were produced, but not as copiously as before, which Mr. Merrill explained by the supposition that the oil had effected decompositions, and liberated portions of the water of combination.

In the second experiment, the absorption of oil was less than in the first, for the specific gravity of the pieces operated on was exactly equal to that of water, while those first treated became heavier than the oil. This observation is important in its bearing upon the treatment of wood. Green timber was more completely saturated than the dry, and the explanation is very obvious. Water, when heated to 212 deg., expands 1,700 times, while the expansion of air in 100 deg. is only $\frac{11}{30}$ of its volume. It follows from this, that if the cells of the wood are filled with air, an increase of temperature, from 60 deg. to 212 deg., will expel $\frac{56}{100}$, or about one-half, while, if the cells are filled with water, the quantity expelled, by being converted into steam, will be thirty-four hundred times as great.

It was also found that the saturated wood was more than double the weight of the dry wood, that the quantity of oil absorbed by white birch was 3.75 gallons per cubic ft., and its weight 32 lbs., at a cost for the oil only of 34 cents. At this rate, the oil required to saturate a cross-tie would cost 90 cents, exclusive of cost of process.

Other kinds of timber are more porous, and would absorb much larger quantities.

It would appear also from these experiments that if the white birch be supposed to have been completely saturated, the volume of the cells slightly exceded the volume of the solid fibre, or that more than half the wood consisted of cavities.

WATER.

Water plays a very important part in all the operations connected with the preservation of wood. As a solvent it reduces metallic salts to the condition of fluids, and allows them to penetrate the cells, if previously emptied; but when the cells are saturated with moisture, nothing else can enter them until it has been removed.

Water is fluid at temperatures between 32 deg. and 212 deg.; but below 32 deg. it becomes solid, and above 212 deg. it becomes in the open air steam. In the conversion of water into steam, a large amount of heat becomes latent. One part by weight of steam at 212 deg. in becoming water at 212 deg. would part with heat enough to raise an equal weight of water 972 deg. This is equivalent to raising $5\frac{4}{10}$ times its weight of water from the freezing to the boiling point.

One lb. of steam will raise 3,657 cubic ft. of air 10 deg., and cause it to expand from 32 deg. to 42 deg. to 3,733 cubic ft.

The heat that would raise 1 lb. of water 1 deg. would raise 1 lb. of air 3.7 deg., and 1 lb. of air = about 11 cubic ft.

Athough water boils at 212 deg. under the ordinary pressure of the atmosphere, the boiling-point may be lowered to any extent in a complete or partial vacuum, and may be increased to any extent by confinement in strong vessels under pressure. Thus water may boil at a temperature less than blood heat, and may be restrained from boiling at a heat of several hundred degrees.

The temperature of steam varies with the pressure. At 212 deg. the pressure is 14.7 lbs. per sq. in.; a pressure of 50 lbs. corresponds to a temperature 283 deg.; 100 lbs. to 332 deg.; 150 lbs. to 363 deg., and 200 lbs. to 387 deg., including the pressure of the atmosphere.

These properties will be found important in discussing the phenomena connected with the treatment of wood.

PRODUCTS OF THE DISTILLATION OF TAR.

Much confusion exists in the use of the names applied to the products of the distillation of tar. They are often misapplied, and the properties of one substance are attributed to others entirely dissimilar. In considering the treatment of wood by oils or vapors, it is very essential that their properties and the conditions under which they exist should be clearly defined.

Specifications of patents sometimes refer to the eupione and paraffine of coal oils, in which these substances do not exist, and other terms are similarly misapplied.

It is necessary to explain therefore that the products of the distillation of tar are very numerous, and embrace a wide range of hydrocarbon oils and vapors capable of uniting with each other in every proportion, but differing greatly in their boiling points and other characteristics. Some volatilize at a very low temperature, and others at a very high one. In the process of distillation every slight increase of temperature will change the character of the product, but the most careful and repeated distillations at fixed temperatures fail to secure perfect uniformity; the result is, more or less, a mixture of different hydro-carbons; and it is a property worthy of particular notice that oils which boil at lower, carry with their vapors others which boil when alone only at higher temperatures.

It does not follow, therefore, that because certain products of distillation have a high boiling-point they will not pass over with vapors of a lower temperature; of course, they cannot be so abundant as at the temperature of their proper boiling-point, but may, nevertheless, be found in appreciable quantities.

These vapors resulting from distillation cannot be maintained in this form at a temperature below that required for their production, but, upon cooling even to a slight degree, are condensed into liquids; an observation of much importance in connection with the treatment of wood.

Coal tar and wood tar differ essentially in their constituents, and these again according to the kind of coal or wood from which they are produced. The following table will exhibit the more important products, so that their properties may be compared.

Products of distillation of

WOOD TAR.

Eupione.

Thin, colorless, aromatic odor.
No taste.
Density 0 655, being the lightest liquid known.
Boils at 116°.
Inflammable.
Insoluble in water.
Composition C_5H_6.

Kreosot.

Fluid at ordinary temperatures.
Water dissolves 1¼ per cent.
Colorless, viscid.
Smoky odor.
Density 1.037.
Boils 397°.
Strongly antiseptic.
Combines with alkalies.
Composition, supposed, $C_{14}H_8O_2$.

Paraffin.

Solid, without taste or odor.
Volatile without decomposition.
Burns with white flame.
Insoluble in water.
Specific gravity 0.870.
Boils 700°.
Composition $C_{20}H_{20}$
Melts at 110°.

Products of distillation of

COAL TAR.

Benzole or Benzine.

Thin colorless, peculiar odor.
Sweetish taste.
Density 0.885, and consequently heavier than eupione.
Boils at 176°.
Inflammable.
Insoluble in water.
Composition $C_{12} H_6$.

Carbolic Acid.

Solid when pure.
Slightly soluble in water.
Melts at 95°.
Smoky odor.
Density 1.065.
Boils 370°.
Antiseptic in the highest degree.
Combines with alkalies.
Composition $C_{12} H_5 O_1, H O$.

Naphthalin.

Solid, faint peculiar odor and taste.
Volatile, without decomposition.
Burns with red smoky flame.
Insoluble in cold water; very slightly soluble in hot water.
Specific gravity 1.048.
Boils 413°.
Composition $C_{20} H_8$.
Melts at 176°.

It will be understood that these are not the only products of the distillation of tar, but they embrace those most worthy of notice. There are in addition various oils and vapors which are more or less mixtures, and also a residuum of pitch.

As the object of the investigation was chiefly to determine the efficacy of certain processes for permeating wood with the vapor of coal oil, it is proper that this subject should receive a more extended discussion; but as other processes are intimately connected therewith, it would seem desirable that a brief description of them should not be omitted. The undersigned proposes, therefore, to consider the subjects under investigation in the following order:

1. The application of the vapors of coal tar to the prservation of wood—the defects of existing modes and proposed improvements.
2. Other modes of preventing decay.

COAL TAR VAPORS FOR THE PRESERVATION OF WOOD.

The application of the vapors of coal tar for the preservation of wood is not new. In 1835 a patent was granted to Frantz Moll in England, and published in 1836, for a process which consisted substantially in placing the wood to be treated in an air-tight chamber heated by means of steam pipes, or "*otherwise,*" to a point sufficient to prevent condensation of the vapors, and the distilling over from retorts, producing what he calls eupione and kreosote, but which should have been called, according to the recognized chemical nomenclature, benzine, carbolic acid, and naphthalin. The claim did not cover any particular form of apparatus or mode of producing the vapors, but the use of such vapors, by whatever name they may be called, applied in that form to prevent decay. It is obvious, therefore, that no patent granted subsequently in the United States claiming the same invention can be valid.

KIND OF OIL USED.

The oil used in the treatment of wood is known at the distilleries under the name of *dead oil.* It is a product of the distillation of ordinary gas tar. At the works at South Boston 40 barrels of tar are placed in 2 stills, from which pipes proceed to a worm contained in a large wooden tank of cold water. The vapors which first pass over, consisting principally of benzine, condense into about 2 barrels of this fluid, which floats on water, and is removed from the vat into which it flows. Next about 10 barrels of a heavy fluid (dead oil) passes over, which has a specific gravity of 1.020 to 1.030, water being 1.000. The contents of the still are then run into another vat, and constitute roofing pitch, the quantity obtained from a charge being about 27 barrels out of the 40. The benzine sells at 25 cts., the dead oil at 9 cts.. and the pitch at 13 cts. per gallon. In England dead oil is worth only one penny per gallon. At 9 cts. per gallon, about 1 cent per lb., dead oil is the cheapest known material for the preservation of wood, and is also the best. It contains variable proportions, but usually about 20 per cent. of carbolic acid.

EXPERIMENTS AT BOSTON.

Experiments were made in Boston with a suitable apparatus to determine the effect of subjecting wood to a bath of heated vapors of dead oil. The apparatus consisted of a tank of boiler iron, 13 ft. long and 4 ft. in diameter. The front end was a heavy casting, 2 in. thick, strengthened by flanges on the inside, held in place by a hinge and supported by a roller running on a plate of iron. The door was packed with a ring of rubber, and secured by 16 bolts to resist the internal pressure. Steam pipes passed into the tank from the rear, and connected with a boiler used for driving the machinery of the mill. The bottom of the tank was filled with pipes through which the steam circulated for the purpose of evaporating the oil. Another pipe opened into the tank through which steam could be admitted when necessary. On top were a thermometer, a pressure gauge, and a vacuum gauge. A low partition, 9 inches high, of boiler iron was placed $6\frac{1}{2}$ in. from the door, across the bottom of the tank, to retain the oil.

One barrel of oil was carefully weighed —405 lbs. It was then emptied into the tank; the wood was introduced, the door closed, and then heat was applied by steam at 80 lbs. pressure above the atmosphere, the temperature due to which pressure being 328 deg. A bent tube passing into a bucket of water was placed on top of the tank, to indicate by the bubbles when the air was expelled and the oily vapors filled the space.

The wood consisted of 24 pieces—spruce, pine, and walnut—part green and part dry. The dry wood, in addition to two years' seasoning in the shop, was baked 15 hours in an oven to insure the expulsion of all free moisture. Each piece was numbered, marked, and weighed, and the total weight found to be 1,590 lbs.

The timber was exposed to the vapors from 10.30 A. M. to 4 P. M., $5\frac{1}{2}$ hours; then upon cooling for 5 hours the vacuum gauge indicated 2 lbs. per sq. in. The steam was again turned on at 9 P. M., and remained until 4 A. M., during which time the wood was exposed to the vapor bath, and the thermometer at the top of the tank indicated 149 deg.

At 10 A. M. the tank was opened. The interior of the tank was coated with large crystals of naphthaline. The space in front of the partition was filled with water, but there was no water whatever on top of the oil. About 46 lbs. of water had escaped from the green wood. The oil had lost only $10\frac{1}{2}$ lbs.; the dry wood had gained 16 lbs. The green wood exhibited no evidence whatever of any permeation by oily vapors; the dry wood very little. The experiment proved that the mode of treatment adopted was entirely worthless, as might have been inferred from the insufficiency of the heat employed, and there was no possibility of increasing it with that apparatus except by the addition of another boiler to provide superheated steam.

A second experiment was made at the suggestion of parties connected with the works, which consisted in exposing the timber for some hours to the action of steam mixed with vapor of dead oil, but the results were not satisfactory. It is proper to observe, however, that samples of paving blocks were exhibited which had been treated by the steam and vapor process, in which crystals of naphthaline were found in the interior, showing a certain degree of penetration, but the condition of the blocks as to dryness before being subjected to the process, could not be ascertained. It is not impossible that in certain conditions this mode of treatment might secure sufficient permeation to increase the durability of short pieces like paving blocks.

OBSERVATIONS.

It is well known that the very small portion of kreosote contained in smoke, will penetrate to the interior of a ham, and cure it. The soluble portions of wood are only 4 per cent. of its weight. If, as high authorities assert, the five-thousandth part of carbolic acid will prevent putrefaction of blood, fæces, glue solution, flour paste, and other substances liable to fermentation, the same proportion should protect the albuminous and soluble portions of wood. And if this be true, only the one hundred and twenty-five thousandth part of the weight of the wood would be required. This is less than the two hundred and fiftieth part of an ounce to a cubic foot, and more than this may be conveyed into paving blocks by the vapor process. While it seems probable that thorough saturation with oils, as in the Bethel process, is unnecessary, a much larger portion than the minimum required to prevent putrefaction would seem to be desirable.

Whatever course of treatment be adopted, or form of apparatus used, certain conditions must be fulfilled to secure satisfactory results, and their consideration will indicate the changes in present modes of operation which appear to be essential to success, for these conditions have not been fulfilled by any processes or plans of operation, that have ever yet been adopted in the treatment of timber.

1. The required condition of the timber as to elasticity must be considered, and it must depend on the uses to which the timber is to be applied. In many situations, as for posts, rigidity is not objectionable, and the impregnation of the cells with resins, or other brittle solids, may give satisfactory results. In other cases, elasticity is as essential as durability. No treatment that would render timber brittle would be applicable to bridges, or beams to sustain weights. Even cross-ties must be elastic. If rendered rigid by the introduction of any substances, with a view to prevent decay, a more rapid destruction ensues from the percussive effects of the trains than from ordinary rot. Dr. Cresson stated very correctly, in conversing on this subject, that the substances introduced to preserve wood for cross-ties must be in a permanently *gelatinous* condition. There must be nothing to prevent that movement of the fibres upon each other, on which the elasticity depends.

Similar conditions are required in the treatment of paving blocks. The original status of the fibre must be maintained. If rendered brittle, the ends of the fibres will break off, and abrasion become rapid. The gelatinous condition is, in this case also, the true one.

2. The condition as to moisture and dryness of the timber will also modify the processes employed. Green timber is often completely saturated with moisture. Its expulsion by ordinary agencies is a very slow operation. Exposed to currents of air, even boards will not become dry in a year. It is an axiom that two substances cannot occupy the same place at the same time; and before any vapors or fluids can permeate the centre of a stick of green timber, the water must be expelled.

The only practical mode of removing water rapidly from the cells of wood, is by converting it into vapor; and this requires heat. Water at 212 deg. is converted into steam; because, at this point, the vapor has sufficient elastic force to overcome the pressure of the atmosphere. But if surrounded by air, or any other fluid, at a higher pressure the water would vaporize slowly, and could not escape rapidly.

The condition then to be observed is, that the wood should be surrounded by a medium under less pressure than the elastic force of the escaping vapor, and in proportion to the difference in the pressure, will be the rapidity of escape. This is a very important observation in its bearings on the treatment of timber.

Another observation is also important. Water, at 212 deg., in passing into steam, absorbs a great amount of heat, which becomes latent. The remaining particles are, therefore, rapidly cooled below the point of vaporization. A cubic inch of water, at the boiling point, in its conversion into steam, at the same temperature, absorbs sufficient heat to reduce, if it were possible, $5\frac{4}{10}$ times its weight of the surrounding particles of water, from the boiling to the freezing point.

It is evident, therefore, if a stick of timber could be heated through to a temperature even above 212 deg., and then exposed to the air, the heat rendered latent by evaporation would cool down the remaining water very quickly below the point at which rapid evaporation would be possible. If in a vacuum, or even a partial vacuum, a larger quantity would be removed. But so rapid is the absorption of heat, by a change of form, from a fluid to a vapor, that a long continued application of heat aided by vacuum would be required for the complete expulsion of air and water from the cells.

3. Assuming that a complete, or at least a sufficient, expulsion of air and water has been effected, the third condition of success in the permeation of wood by oleaginous vapors is a temperature sufficiently high to prevent condensation.

The hydrocarbons which distil at certain temperatures are rapidly condensed at lower temperatures; and if vapors distilled at 400 deg. pass into a receiver or tank heated only to 200 deg., there will be an immediate condensation into a liquid, which, falling to the bottom, cannot permeate the wood, which receives, therefore, only the more volatile and least valuable products.

To prevent this condensation, the heat of the tank must be raised nearly or quite to 400 deg.; but if this be done, a new and serious difficulty is presented: the water, expelled from the wood or condensed from the steam, would be converted into vapor, having a pressure of 18 atmospheres, or 270 lbs. to the sq. in., which would blow a large tank to atoms ; and yet, as has been stated, carbolic acid is, of all others, the most important principle contained in coal oil ; and carbolic acid boils at 370 deg.; and a much lower temperature in the tank will not maintain it in the form of vapor, or allow it in large quantities to permeate the wood ; most of it will be carried off by the tar, and lost. It is probable, also, that a temperature of 400 deg. would make the wood brittle.

No doubt carbolic acid does pass over at lower temperatures, and does, to a slight extent, permeate the wood, being carried over by the mechanical action of vapors at lower boiling points ; and it is not impossible that in this way a sufficient quantity may combine with the fermentable elements to protect them effectually. Time, experience, and careful observation can alone determine these questions. But there is one conclusion to which this discussion leads, which is, that there can be no permeation of the fibres of wood in large quantities with carbolic acid, by the vapor process, without using a degree of heat, which, in a large apparatus, would be dangerous and inadmissible, even if experience should prove that the elasticity of the fibres is not destroyed thereby.

On a small scale, and with strong apparatus, wood can no doubt be treated effectually by vapor alone. As the strain per sq. in. upon the iron plates of a tank would be directly as the diameter, a pressure of 200 lbs. per sq. in., in a tank 1 ft. in diameter, would become 1,400 lbs. per sq. in. if the diameter with the same thickness of metal were increased to 7 ft. It is probable that in a very small tank, aided by a bath of oil, satisfactory results can almost always be secured. And there is reason to believe that in this way specimens have been prepared if they have not been, as is most probable, dipped in the oil.

Can there be any introduction of carbolic acid into the cells of wood without employing a dangerous degree of heat?

This is an important question, and it would seem from the principles that have been enunciated, that an affirmative answer can be given.

The first step in any process to fill the pores of wood must be the expulsion of the water from the cells, and it is more difficult to create a vacuum in the cells of dry wood than in those which contain some moisture, since water in its conversion into vapor, expands more than 3,000 time as much as air at the same temperature.

If, when the cells are empty, the tank containing the wood could be filled with liquid oil, and then immediately drawn off, there would be but a small amount of the oil absorbed, for the progress of a dense fluid into the pores would be slow. If, then, steam, air or the vapors from a still, or from any other source, should be admitted, even at ordinary atmospheric pressure, they would penetrate into the empty cells in the interior of the timber, and carry with them a very much larger portion of the liquid carbolic acid and hydrocarbon oils than the vapor process alone could introduce, at the same time the quantity would not be so great as to render the process expensive. The fluid oil also would introduce into the wood the denser and most valuable products that could not be volatilized, giving the wood so treated properties which the vapor process alone could not possibly communicate.

An apparatus that would fulfil all these conditions could be readily constructed, and the expense would actually be less than that now in use, while in safety and efficiency there could be no comparison. In fact, an apparatus was constructed by the writer in 1862, after a series of experiments on flax cotton, for the purpose of impregnating wood with oils, resins, tallow, paraffine, coloring matters, etc., and of dying fibres by the application of heat, vacuum, and pressure, which involves precisely the principles enunciated in this report, and was used in the laboratory of the Treasury Department at Washington.

OTHER PROCESSES FOR PRESERVING WOOD.

James B. Francis, in a recent publication on the preservation of timber, states that 47 patents have been taken out for preserving animal and vegetable substances, including timber. Most of these processes are valueless; those which have commanded most attention will be enumerated and briefly described.

The Bethel Process was patented in

1838, and consists in impregnating timber with the dead oil from the distillation of coal tar, the preparation of which has been described. Joshua Merrill, Esq., of the Downer Kerosene Works, examined this process personally while in England, and his description will be given.

The tank which contains the wood to be treated is of boiler iron. At the bottom and sides are numerous pipes for heating by steam. The timber is placed on an iron car and run into the tank. The tank is filled with dead oil, which is then heated by the steam coils. A pressure of 100 lbs. per sq. in. is applied by means of a hand pump. A thermometer is used to note temperature. The duration of the process is 12 hours. Timber 12 in. sq. is fully impregnated, as is proved by boring holes. An air-pump is also used in connection with the operation, no doubt to remove the escaping air and steam, and relieve the pressure while the wood is being heated in the oil.

This process is conducted on correct theoretical principles; and the results are such as to secure thorough saturation. The timber is heated in oil, the water vaporized, the steam and air which would resist the escape of water from the pores is removed by an air-pump, a vacuum is thus formed, and lastly, the oil is forced in by a pressure of 100 lbs. to the sq. in. applied by a hand pump.

Such a process must be effective, and Mr. Merrill says it is, but the result is saturation. It appears that wood will absorb its own weight of oil, and this is probably at least a hundred times as much as would seem to be required as a preventive of decay. Even in England, where dead oil costs 2 cents per gallon, the process is considered expensive. In this country, where oil is worth 9 cents, the cost of oil per cubic foot would be 33 cents, and including fuel and other expenses the cost of treatment could not be less than 40 cents per cubic foot, if the process should be pushed to the point of saturation.

This is the most effective process for preserving timber known. No case has yet been cited of the decay of a Bethelized stick of timber, or of its being attacked by worms even in the most exposed situations. The heat employed is moderate, and the elasticity of the fibre is probably unimpaired, but the combustibility of the wood is greatly increased, and in a dry climate the use of the process for bridge timber, cars, and railroad purposes generally, would be inadmissible; even paint would not protect such timber from fire, for the exudation of oil causes the paint to scale off.

For these reasons the Bethel process has very properly found no favor in the United States.

Kyan's process was patented in England in 1832, and soon after in this country. "This process, called Kyanizing, consists in immersing the wood in a dilute solution of corrosive sublimate, until it is thoroughly saturated; or if haste is an object, injecting the solution by pressure in a closed vessel, from which the air is first partially exhausted. This process was very extensively adopted in England, and to some extent in this country. It was undoubtedly a valuable invention, and when faithfully executed, it seemed effectually to arrest the rapid decay of timber in exposed situations. The difficulty of carrying on the process, in any way excepting by immersion in open tanks (which is intolerably tedious), arising from the powerful action of the solution upon the common metals, the great cost of the material used, and no doubt, to some extent, the introduction of other processes, has led to the abandonment of Kyanizing in this country. In England, also, it has been given up, where, in addition to the causes operating in this country, the gross frauds practised by the company owning the patent, and by parties carrying on the process, threw a discredit upon it, which with fair dealing it would not have been subject to."

The quantity of solution absorbed and the cost of treatment are the important practical points to be determined.

The absorption of solution would, no doubt be about the same as with the solution of cloride of lime, which Mr. Francis states is 30 imperial gallons of dilute solution containing $\frac{1}{50}$, by weight, of dry salt to 50 cubic ft. of timber. An imperial gallon of it weighs 9 lbs. The solution absorbed would be $5\frac{4}{10}$ lbs. per cubic ft., and the dry salt therein contained, $\frac{1}{10}$ of 1 lb. The cost per lb., in large quantities, is 75 cents, and the value of the salt used per cubic ft. would be $7\frac{1}{2}$ cents, the whole cost of the process possibly, 10 cents.

Margary's process, patented in 1837, consists in immersing the timber in a solution of sulphate of copper. The cost of this salt is 11½ cents per lb., in large quantities, and allowing an equal absorption as with corrosive sublimate, the quantity required per cubic ft. would cost about 12 mills. This process, although extensively used at one time, is said not to have continued in favor.

"*Payne's* process, patented in 1841, consisted in using two solutions in succession, which mutually decompose each other and form an insoluble substance in the pores of the wood. In this manner sulphate of iron and carbonate of soda are said to form an insoluble compound in the pores of the wood, preserves from decay, resists the attacks of insects and renders the wood less combustible. Mr. Francis states that the process has not maintained itself in England, but in France has met with more favor." The cost is not known.

Boucherie's Process.—This process is much used in France for treating telegraph poles and cross-ties, and the traveller along the railways will see at many points elevated tanks from which pipes proceed to rows of sticks laid side by side on platforms, the butts being elevated a foot or two more than the points. The butts are covered with caps, a separate cap to each stick, which fits tightly on the end and is luted with clay or some other material to prevent the escape of the solution. The pressure from a head of 40 ft. or more in the tank, and the downward inclination of the sticks, causes the solution to be forced through the pores and drip from the small end, carrying with it much of the sap and other fermentive matters. This process dispenses with immersion in the fluid, and is simple and inexpensive.

Dr. Boucherie claims that the process accomplishes two objects, that of expelling the sap and of filling the pores with a preservative solution. It is stated that this method has been attended with complete success. The invention seems to be confined to the method of applying the solution and not to the solution itself. The salt used in the process would constitute the principal expense.

Burnettizing Process.—The following description of the Burnettizing process as practised at Lowell is from the report of James B. Francis, Chief Engineer:

"In 1838, a patent was granted in England to Sir William Burnett, for a process for preventing decay in certain vegetable and animal substances, by the use of chloride of zinc. This process called Burnettizing, has been extensively used in England, as a preventive of the decay of timber; and it has been more extensively used in this country, for the same purpose, than any other process. No patent was taken out for the United States. It was first introduced at Lowell, Massachusetts, where, in 1850, the Proprietors of the Locks and Canals on the Merrimack river, at the joint expense of the manufacturing companies, erected the necessary apparatus for carrying on the process. The original intention was to prepare timber only for their own purposes; it was soon found, however, that the apparatus was capable of preparing much more, and that a more extended use would diminish the cost. Accordingly, large quantities of lumber, of various kinds, have been prepared for others, principally for the Lowell Bleachery, and the railroad companies in the vicinity.

"The charges now are—

"For spruce lumber, $5.00 per 1,000 feet, board measure.

"For all other kinds of lumber, $6.00 per 1,000 feet, board measure.

"For spruce shingles, 67 cents per 1,000.

"For other kinds of shingles, 75 cents per 1,000.

"For lots of lumber 100,000 ft., or more, special contracts are made, usually 50 cts. per 1,000 less than the above prices.

"Spruce is prepared at a lower price, as it takes up much less of the chloride of zinc than pine, or other kinds of timber in common use.

"About 1,000,000 ft., of board measure, have been Burnettized annually since 1850 at this establishment. There has been scarcely time yet, to show fully the results of the process here; enough has been seen, however, to show very clearly, that although it is not in all cases a sure preventive of decay, the advantages are more than sufficient to justify its application to most kinds of timber in common use, and in situations favorable to rapid decay. It has also a distinct effect in rendering wood less liable to warp and crack, when placed in dry situations.

"The apparatus at Lowell consists of a

horizontal cast-iron cylinder, in which the timber to be prepared is placed; this cylinder is 60 ft. long, and 5 ft. diameter inside, with one head movable; the iron generally an inch thick. A pair of rails, about 2 ft. gauge, are laid in the bottom of the cylinder, and also on the same line and level, about 75 ft. outside the cylinder; a low truck, about 60 ft. long, runs on these rails. When it is required to charge the cylinder with timber, this truck is drawn out, loaded, the load chained down to prevent its floating, and the truck then drawn into the cylinder.

"A little below the level of the cylinder and parallel to it, is placed a wooden cistern, to hold the solution while the cylinder is being loaded and unloaded, and at times when the apparatus is not in use; this cistern is about 50 ft. long, 7 ft. wide, and 4 ft. deep, and was originally constructed for Kyanizing by immersion. The air-pump is 12 in. in diameter, and 3 ft. stroke. The force-pump 4 in. in diameter, and 2 ft. stroke. The pumps are worked by a small steam-engine of about 15-horse power, which also works the windlass by which the truck is drawn in and out of the cylinder. The boiler of the engine is also used in winter to supply steam to thaw frozen timber; this is done by admitting steam into the cylinder, charged with frozen timber; for several hours before the vacuum is obtained. The steam-engine and boiler are both much larger than necessary for these purposes.

"The chloride of zinc is received from the manufacturers in the form of a concentrated solution, containing about 55 per cent. of the dry chloride. The amount taken up by the wood varies very much, depending upon the kind, dimensions, and dryness of the wood. As the process is conducted at Lowell, it varies from about 10 lbs. to 40 lbs. of the concentrated solution to 1,000 ft, board measure, or say, from 2 to 8 oz. to a cubic foot.

"Unseasoned wood is saturated with great facility and completeness, under the pressure used at Lowell; with seasoned wood it is not so, and although a larger amount of the solution is absorbed, it is frequently found that portions of the interior of the wood have not been reached, even in plank and other stuff of moderate dimensions. Wherever practicable, green and seasoned wood should be differently treated—the latter requiring more time, and, to avoid waste, a weaker solution.

"The most remarkable instances of the preservation of wood, by Burnettizing, are in some of the woods which decay with such rapidity as to be almost valueless. Poplar, for instance, is useless in its natural state, as a fencing material. Trials at Lowell, however, show that, when Burnettized, poplar is a durable wood, apparently as serviceable as chestnut, for posts."

Burnettizing is not as much in favor as formerly. Experience proves that while the process is beneficial to poplar and other soft and perishable woods, it has no effect upon durable kinds, or upon those which contain tannic acid or resins.

Robbins' Process.—The process called the "Robbins" in this country is identical with the Moll process, for which a patent was granted in England in 1835. It consists in the use of the vapors of dead oil. The efficacy of this process depends upon the degree of permeation of the vapors, and the conditions essential to success have been very fully presented and discussed. The numerous testimonials in regard to the efficacy of carbolic acid, the most important constituent of dead oil, would seem to indicate that there can be but little question of its ability to arrest decay and preserve wood indefinitely if actually introduced into the pores; but it has also been shown, in the consideration of this subject, that the vapor bath does not secure this object with any certainty; and of several pieces subjected to the same treatment, in the same tank and at the same time, some may be permeated with vapor and others not at all, according to dimensions, contained moisture, and other conditions of the material operated upon.

Heineman Process.—A company has been formed in New York for the purpose of treating wood with rosin and other substances injected by means of heat and pressure.

No doubt rosin and many other solids, such as wax and paraffine, will preserve wood effectually if the water is first expelled and a vacuum created; but as they do not possess the powerful antiseptic properties of carbolic acid, a much larger quantity of the material will be required, and the cost will be greater.

There are other processes besides Payne's, in which a metallic salt is first introduced in solution, and other substances are then attempted to be forced into the cells so as to effect a double decomposition, and make deposits of insoluble compounds in the interior of the wood; but an examination of the processes shows that this result cannot be secured by the means employed, and this conclusion is confirmed by chemical tests. The originators of such processes seem to have assumed that because certain chemicals exhibit certain reactions in test tubes and glasses when brought into contact in solution, and form insoluble precipitates, that a similar action must take place in the pores of the wood. The error lies in the fact that the processes employed do not secure that actual contact in the ligneous cells that can be obtained so readily in mixing the contents of glasses.

In one of the processes employed, a saline solution is injected into the cells by vacuum and pressure, and in short pieces, as paving-blocks, there is evidence that this part of the process is successful. The next step is to exhaust the air from the tank containing the wood, then introduce another solution, supposing, that the first will be decomposed and deposits formed in the cells; but in this a great mistake is committed. Air can be removed from the cells by a vacuum, because it is elastic; but water can not except so far as it is driven out by the mechanical action of the escaping air. So long as the cells remain filled with water, not even a thousand pounds pressure to the square inch can force any other solution in to them. There is only one way in which the desired result can be secured: the non-elastic must be converted into an elastic fluid, water must be converted into vapor by the application of heat and vacuum ; then the salt contained in the first solution will be deposited in the cells, the cells emptied of water and prepared to receive a second solution capable of being decomposed by the saline deposit of the first.

It is not impossible that valuable results might be secured and timber rendered less combustible and more durable by a properly conducted process of double decomposition, forming insoluble precipitates. Soluble silicates, followed by chloride of calcium, may possibly give satisfactory results; but in all cases applications of heat, and vacuum, will be necessary to remove the water of the first solution, deposit the salt, empty the cells, and prepare for the introduction of the second.

The writer devoted several days to an examination of the portfolios and records of the Patent Office, and finds many processes which approximate very nearly to the conditions essential to success, but they all fall short of attaining this result.

One of the nearest approximations to the conditions of success is found in the specifications of a patent granted to Messrs. Clarke, Hodley & Clifford, of Buffalo. The wood is heated in a *current* of steam to a certain degree, then a fluid bath is used as a condenser, and it is assumed thus the steam expels the air and water.

The current of steam is a new idea, and it may produce more effect than the application of steam not in motion, although no good reason for it can be perceived; but still there can be no movement of the water in the interior cells until it is converted into vapor; the transmission of heat from the exterior is very slow, the steam presses against the outside of the wood with great force, even if there is a current, and retards evaporation, and if allowed to escape more rapidly, so as to relieve the pressure, then the heat is reduced by the expansion. The idea of creating a vacuum in the wood by steam or otherwise, and then following by a bath of oil or other fluid, is just right; but the process described does not accomplish the object, and this is precisely the difficulty with all the patented processes: they do not insure the expulsion of the water.

A. R. McNair, of New York, places wood in a cylinder; heats by steam; creates vacuum by condensation; introduces vapors of coal-oil at a temperature of 392 deg., and follows this by rosin to close the pores. There are many ingenious points in the process, but the radical defect still exists, and needs no further discussion.

The patents on the treatment of wood are very numerous. Only a few more will be briefly enumerated.

W. H. Smith encloses piles with a coating of earthen-ware as a protection against the teredo.

Eben L. Cowling uses steam impregnated with vapor, in which respect his process resembles that of Jos. F. Paul.

Joseph Calkins uses steam to heat the wood, followed by hot vapors and pressure.

George Palmer heats the surface of the wood with fire, and then applies a composition.

George Pustkuchen encloses wood in a cylinder, creates vacuum, and saturates with tar.

Silas Constant and John Smith heat wood in tanks by air, and then expose to vapor of tar.

Voorhees and Custis dry the wood by vapors of oil, then condense, then treat by vapor of oil at 370 deg., the evaporation being carried on in the same chamber which contains the wood, and not in separate retorts.

This list could be continued to a much greater extent, but the illustrations given will probably be considered sufficient.

It is unnecessary to detail all the processes that have been proposed or patents granted for preserving wood from decay. Every conceivable substance, solid, fluid, or in vapor, that could be supposed to have any efficacy, has been suggested. The use of such substances is not patentable, but certain modes of injection and forms of apparatus may be. No patent which covers broadly the use of coal oil or other vapors, or the use of paraffine, wax, or rosin, to preserve wood, can be valid, and yet several patents rest on just such claims.

After completing the experiments in Boston and the examinations in the Patent Office, the writer procured a steam boiler with the use of steam from a factory, and continued experiments in Philadelphia. Pieces of green timber, carefully weighed, were placed in the boiler and heated for half an hour by the direct application of steam; the steam was then condensed so as to allow the water to evaporate from the timber in vacuo. The steam was then turned on again and the process of alternate baths of steam, followed by successive condensations, was repeated for some hours, the condensation being effected in the same cylinder which contained the timber. The result was a total failure; the timber at the end of the process weighed precisely as much as at the beginning. The explanation is obvious, the steam and time restored to the timber the moisture which the preceding application of heat and vacuum had removed.

CONCLUSIONS.

The conclusions from the investigation are :

1. That so long as the cells of wood are occupied by air and moisture, no preservative solutions can be introduced, and the expulsion of air and water must be the first step in any effective process for preserving timber from decay.

2. That water can be expelled by a long continued application of heat, but air only by expansion in a vacuum, and the combination of heat and vacuum will secure the most rapid expansion both of water and air.

3. The preservative fluid must be introduced while the cells are empty, consequently the process must be carried on in vacuo.

4. That no pressure, however great, applied externally to the surface of timber, can force any fluid into the interior so long as air or water is contained in the cells. When air alone is present there may be penetration to a limited extent, superficially, but water is practically incompressible. If, however, the pressure is applied at one end only of a stick, as in the Boucherie process, a fluid may be forced through and exude from the other end.

An apparatus to fulfil the conditions which, from the preceding discussion, appear to be essential to success, must be founded on a process similar to distillation in vacuo. It must consist of at least two vessels, one a receiver corresponding to a retort in which the material can be placed and subjected to the action of heat, the other a condenser in which all escaping vapors can be condensed and the vacuum maintained during the process in both vessels.

The condenser may be of much smaller capacity than the receiver; they should communicate by pipes furnished with stopcocks, and both be supplied with thermometers, vacuum gauges, and pumps.

As an illustration, suppose wood is to be impregnated with dead oil or any other fluid. The receiver must be filled with the wood to be operated on, the door closed air-tight, and the air expelled from both the receiver and condenser.

The expulsion of the air may be effected in various ways.

1. Steam may be admitted at one end to drive out the air at the other end; the subsequent condensation of the steam should leave a vacuum, but in the experiments of the writer, this plan has been only partially successful.

2. The air may be exhausted by an air-pump, but a perfect vacuum cannot in this way be secured.

3. The vessels may be filled with water and the water removed by a pump below the level of the bottom into which the water flows. This should remove all the air excepting that which escapes from the cells.

4. As the atmosphere supports a column of water 33 ft. high, pipes may lead to a tank at a level about 40 ft. lower, where the location is favorable, and thus by filling the vessels with water and opening cocks to allow the water to flow by gravity into the tank, a very perfect vacuum could be produced. This arrangement would be particularly favorable for maintaining a vacuum in the condenser; a pipe in the condenser could throw jets of water in spray from numerous fine perforations, and the water would constantly flow into the tank 40 ft. lower, maintaining a constant vacuum without the aid of pumps. This object can be accomplished in almost any locality by placing the condenser at the top of a building or on trestle work.

Assuming that a vacuum has been created and provision made for maintaining it during the whole process, the next step will consist in the application of heat, which may be done most conveniently by steam-pipes introduced in the receiver. The length of time during which the timber must be subjected to the baking process will depend upon the dimensions of the sticks, and can only be determined by experiment.

It is obvious, however, that the circumstances are favorable to the most rapid evaporation possible; the temperature can be regulated at pleasure, and the removal of pressure by vacuum will give a very low boiling point. As the vapors pass over they will be immediately condensed.

Should the vacuum become vitiated by the escape of air from the cells, it may be improved by the use of an air-pump. The condition of the vacuum will be indicated by the gages.

When sufficient time has been allowed for the wood to dry thoroughly, cocks must be opened connecting the bottom of the receiver with a tank of dead oil, at a lower level. As a vacuum exists in the receiver, the atmospheric pressure will force up the oil and the timber will be immersed in the fluid. When the immersion has continued a sufficient length of time, which also must be determined by careful experiment, cocks may be opened at the top of the receiver to admit air. The oil not absorbed will immediately flow back to the tank from which it was taken, the air pressing upon the exterior of the cells, which are partially filled with oil while a vacuum exists in the interior, will force the oil before it, and thus coat in its progress the interior of the cells. It is probable that in this way a sufficient amount of dead oil may be introduced into the cells to prevent fermentation and decomposition while still far below the point of saturation, and the process may prove rapid and economical.

Instead of admitting air in the manner proposed to expel the oil from the receiver, it is possible that better results may be obtained by allowing the oil to remain until it becomes heated by the steam coils and the vapor collecting at the top expels the oil and penetrates the pores.

Too much oil might be introduced by this mode of treatment, and it is probable that the introduction of air, followed perhaps by a second bath of oil to close the cells superficially and exclude moisture, would give the best results. All these and other questions that may arise can be promptly settled by experiment, and in no other way.

This process of drying in vacuo would be well adapted to the rapid desiccation of fruits, vegetables, fish, meats, etc., with a view to preservation.

The writer does not claim that he has solved the important problem of preserving timber from decay. Before he could satisfy himself or others, a series of continued experiments with suitable apparatus would be required; but it will not be considered egotistical to assume that, in several months of experiment, something has been learned. He is satisfied, at least, that none of the ordinary processes will preserve wood economically, and there is, in his opinion, no surer avenue to success in any investigation, than the study of failures and their cause. He has witnessed too many failures to be sure of anything until it has been proven, but believes that in the processes indicated there are strong reasons to expect success.

MOUNTAIN LAKE, Giles Co., Va.

TREATMENT AND UTILIZATION OF SEWAGE.

From "The Engineer."

Probably one of the most difficult tasks with which either a single individual or a body of men can be charged is to collect accurate and reliable information upon any given subject. Sometimes this difficulty may proceed from the fact that there is really very little information of any kind to be obtained, but in by far the greater number of instances it does exist, but cannot be got at. In giving evidence before committees, commissions or other legally authorized tribunals of inquiry, people will volunteer statements by the dozen, which are totally irrelevant to the matter at issue, and, with invincible obstinacy and stupidity, keep back every circumstance which is of vital importance to the inquiry. It cannot be denied that there is a general unwillingness, a sort of dog-in-the-manger tendency manifested by those who possess information, as to imparting it to others. This reluctance would be easy of comprehension if the persons who desired the knowledge intended to apply it solely to their own benefit; but when it is demanded in behalf of the interests and welfare of the whole community, it might be reasonably expected that it would be cheerfully and readily afforded. There is still a third reason, and the one which no doubt is the most active in preventing committees of inquiry arriving at the truth of the particulars they are anxious to verify. It is that while the parties interrogated are really in possession of the information required, and are willing to impart it, they are practically unable to do so. The inability is due to the want of method or system which has distinguished their arrangements. If a company, or local board, be requested to furnish for the benefit of the public, an accurate statement of various operations which may have been conducted by them they are very frequently unable, however willing, to comply with the request. From the loose manner in which many of these companies and authorities carry on their proceedings, from the want of established data, or from the want of a proper organization and efficient superintendence, the collection and abstraction of independent facts becomes well nigh an impossibility. This remark will be found to be especially applicable to the item of cost. Unless estimates are vouched for by strong corroborative evidence, and the accounts are remarkably clear and explanatory, we have long since failed to put any faith in them. The only man who knows what a job costs is the contractor, and that knowledge he very wisely invariably keeps to himself.

If there is one branch of the profession more than another concerning which accurate and reliable facts are of the greatest value, insomuch as they are very few in number, it is that of sanitary engineering. Notwithstanding that there are numerous towns in which various sanitary measures, widely differing from each other, have been either carried out or attempted to be carried out, and of the success or failure of which the local authorities must be well aware, it is nearly impracticable to obtain from them any information on so desirable a subject. From the report of the committee appointed in 1870 to inquire into the "Treatment and Utilization of Sewage," it appears that out of a large number of local authorities who were applied to to assist the committee in their task, by furnishing them with the results of their experience, but very few responded to the request. The committee had a form printed, embodying a series of questions, which they sent to the respective towns, and to which they requested answers, but only eight of them were returned sufficiently filled up to be of any practical utility. It must be admitted that so meagre a return is not very encouraging to those who are anxious to arrive at an impartial conclusion respecting the advantages of the many sanitary schemes and projects which have from time to time been brought before the public. If, moreover, we subtract from these eight towns from which data have been obtained, Beddington, Norwood and Carlisle, where sewage irrigation has been in progress for eight or ten years, and the results long since recognized as succesful, there are really only five which may be said to furnish corroborative testimony. Again, from these five may be eliminated the town of Leamington, since out of the forty-nine questions contained in the printed form, there are only twelve answered which relate to the subject, none of which are of any importance. So that, summing up, we find that but four towns have supplied any really valuable information, and of these the sewage works of one, Cheltenham, have been in operation only one year; so that it would be somewhat premature to form a definite conclusion in this case, although, judging by analogy, it will no doubt prove another successful example of the utilization of sewage by irrigation. There is the greater reason that this anticipation will be fulfilled, as Cheltenham is naturally well situated for the disposal of its sewage upon this principle, the relative level of the land in the vicinity of the town which is appropriated to this purpose permitting the sewage to be conveyed solely by gravitation. It must be acknowledged that while there is no doubt but that pumping can be employed to advantage with regard to sewage irrigation, and must be used in the majority of instances, yet wherever gravitation will effect the removal and utilization of the sewage, it very materially increases the chance of a pecuniary profit resulting from the undertaking. It is very fortunate for the cause of sewage irrigation that Croydon is so situated that its sewage can be disposed of without the aid of pumping. Had it been otherwise it is questionable whether the irrigation system would have received even the partial development that has attended it.

Granting that very little fresh information on the subject of their inquiry has been obtained by the committee referred to, still several important points have been confirmed thereby. We have invariably, when treating of this question, drawn attention to the necessity of draining the land upon which sewage is utilized. Unless this be thoroughly well effected the sewage will not be utilized to a maximum, and moreover, the effluent water will not reach the requisite degree of purity. There is very little doubt that recent experience has shown that cubical irrigation will supersede superficial, as the former, combined with a thorough under drainage of the soil, possesses superior advantages over the latter with respect to both the sewage and the land itself. It is stated in the report of the committee that if sewage be made to percolate through several feet of soil that has been deeply drained, before it be permitted to flow away, oxidation proceeds as well in winter as in summer, and that whatever amount of nitrogen may be lost, it escapes in an oxidized and inoffensive form. Speaking broadly, it may be said that the utilization of sewage and the purification of the effluent water, are, within certain limits, in proportion to the depth of the soil through which it is caused to percolate. The difference between cubical and superficial irrigation, therefore, is, that in the former the sewage flows through, and in the latter over, the land. Some interesting results were deduced with regard to the effect of these two methods of utilizing sewage upon its temperature. When the sewage was passed throgh the soil the reduction of the temperature was in winter much less than when it flowed over the surface. Again, in summer the former process cools the sewage; while the latter heats it. Roughly, the loss of temperature might be taken as a measure of the degree of percolation and consequently of purification, that the sewage undergoes. By further experiment and confirmation this test might be rendered sufficiently accurate to afford valuable results, more specially as its simplicity and ready application are obvious. A couple of thermometrical observations, one made upon the raw sewage, the other upon the effluent water, would supply all the data necessary. Though we have expressed ourselves as somewhat sceptical respecting the alleged cost of works, yet as the report under notice has given a very elaborate statement of the cost of the Tunbridge Wells sewage farms, it is incumbent upon us to make a few remarks thereon. In the interest of all those towns which presumably will have to establish sewage farms, it is only fair to mention that the cost of those at Tunbridge Wells is exceptionally high. The cost of preparing the ground and the necessary carriers, pipes, and fences, comes to as much as £38 per acre. It is admitted that these works have been constructed in a most expensive manner, probably much more so than was absolutely necessary, and it is extremely fortunate that the sewage can be applied on the gravitation principle. If pumping had been requisite, considering that the population is under 20,000, the returns must have been very large to have prevented a heavy burden falling upon the ratepayers.

It has often been alleged by those who are not advocates for sewage farms that cattle fed on sewage-grown grass were liable to suffer from the presence of internal parasitic life. Obviously an allegation of this kind, particularly when made by persons of authority and ability, presents a very serious aspect, and is calculated to create considerable alarm in the minds of the public, besides being exceedingly prejudicial to the cause of irrigation. With the view of setting this matter definitely at rest, the committee sent the carcase of an ox which had been fed for two years on sewage-grown grass, cut from Mr. Hope's farm, near Romford, to be dissected. Dr. Cobbold undertook the operation, and several members of the committee were present on the occasion, and, after a very careful and searching examination, not the last trace of any parasites could be observed. As a proof of the efficient manner in which the operation was conducted, it may be mentioned that several of the muscles were dissected through and through. The result was the same, denoting the complete absence of all entozoa. It must be borne in mind that the animal was fed exclusively upon vegetable products, cut and carried from the land, and did not graze on the farm. It is not, however to be understood from this remark that cattle which graze upon sewage farms are necessarily subject to the presence of parasites, for their germs would in all likelihood pass into the soil and not remain upon the plants. The committee report with respect to Breton's farm, that there is a remarkable absence of those molluscan and insect forms of life which frequently play the part of intermediary bearers to entozoal larvæ. The sewage appears to drive away or kill these creatures. An analysis of the "flaky vegetable tufts" collected from the sides of the carriers, showed that, though they contained numerous active free nematodes, they were perfectly free from the ova of any true entozoon. It is evident that the greater the depth to which the sewage penetrates into the soil the less chance there is of any parasitic germs remaining on the surface. This constitutes another argument in favor of cubical irrigation. Slowly but surely the truth of the irrigation principle is forcing itself upon the minds of the public; doubts that once existed, particularly with regard to its application, are disappearing. Local authorities are beginning to "accept the situation," and to recognize at last that there is no other means of profitably utilizing sewage on a large scale. The various deodorizing and disinfecting schemes are nearly all defunct. It is not, however, to their failure that sewage irrigation will owe anything for its future development, as even during their imaginary success they never proved anything against the principle.

COMPRESSED AIR ENGINES.

From "Engineering."

The plan of working tramway cars or other vehicles by turning to account the power stored up in a supply of compressed air, is one which has been frequently proposed, and which has, in several instances, been carried out in practice with results in some cases satisfactory, and in others of a decidedly opposite kind. In America, in particular, this system of propulsion has attracted much attention, and we, from time to time, receive from the United States reports of the more or less successful trials of various modes of carrying out the system in practice. It unfortunately happens, however, that the data available concerning these trials are generally of the vaguest possible kind. They inform us, perhaps, that a car fitted up with a compressed air engine made such and such trip in such and such time, and that the performance was successful, or that it failed in some way or other; but we are doubtful if any really complete series of experiments has ever been made with one of these engines, or at all events we are unaware of a report of any such experiments having been published. By a complete series of experiments on a compressed air engine we mean a trial, or series of trials, of the engine on the line of which the gradients are known, and with a load also known, there being taken during the run or runs, a continuous series of indicator diagrams from the cylinders, and contemporaneous observations of the temperatures and pressures of the air in the reservoir, and in the pipe leading to the cylinder, besides a record of the temperature of the air as it is discharged from the cylinder into the atmosphere. The barometric pressure and the temperature of the external air, and the amount of moisture present should also be noted, while a record might also be kept of the temperatures of the external surfaces of the reservoir, of the pipes communicating with the cylinders, and of the cylinders themselves.

From such a series of observations as that to which we have alluded, some valuable data might be deduced bearing upon the construction of pneumatic locomotives, and we believe that a great deal of the time and money at preset spent in so-called practical experiments might be saved. It would be possible, for example, to deduce from such observations, information respecting the rates at which the air during expansion took up heat from objects with which it was in contact, and to determine the extent to which the heat converted into work was replaced by other heat absorbed by external sources. These data being obtained, it would become possible to determine approximately the best proportions between the initial and working pressures of the air used (for in most cases the pressure of the air is materially reduced on its way from the reservoir to the cylinders), the best cylinder capacity to employ for a given amount of work to be performed, and the best place to make up—or try to make up—the loss of heat due to work done. The determination of these points, even approximately, would be of immense service to those who are endeavoring to bring pneumatic propulsion into use, and instead of working in the dark, as at present, most—if not all—of them appear to be doing, we should earnestly recommend them to carry out such trials as those of which we have spoken. If they were to do so we feel certain that the cause in the progress of which they are interested would be most materially benefited.

From the time that the system of working engines by compressed air was first proposed, down to the present, one of the most annoying practical difficulties with which the advocates of the system have had to struggle, has been the excessive refrigeration caused by the expansion of the air, and the consequent freezing of the moisture contained in it; this freezing resulting in the blocking up of the pipes and passages with ice. To avoid this trouble, it has been proposed to heat the air on its way to the cylinders by passing it through pipes enclosed in a stove or furnace, or to envelop the cylinders in jackets through which the products of combustion of a stove might be made to circulate; while, in the case of the submarine boats built at St. Petersburgh some time ago for the Russian Government, and which are driven by engines worked by compressed air, the plan was resorted to, of connecting the engines with the reservoirs by a number of pipes, and shutting off the current of air through any of those pipes in which ice might accumulate, so that the latter might be thawed by the absorption of heat from external sources. In some cases upwards of thirty pipes were used to connect the engine with the reservoir of air. This plan of employing a number of connecting-pipes no doubt meets a portion of the difficulty; but it is a plan requiring more attention than it is desirable should have to be bestowed on the working of engines fitted to tramway cars, while the proposals to heat the air on its way to the cylinders, by passing it through tubes exposed to the fire of a stove or furnace, or to heat the cylinders by means of jackets traversed by products of combustion, are also open to objection on practical grounds. Amongst other things there is, if either of these latter plans be resorted to, always a risk of giving to the air, prior to its admission, or to the cylinder itself, such a temperature as to destroy the lubricating material employed, and thus cause "cutting" to take place.

Having objected to the principal plans proposed for obviating the difficulties resulting from the refrigeration of the air during expansion, it is only fair that we should point out what we believe to be a preferable mode of getting over these difficulties. This mode consists simply in the employment of a hot-water jacket for both the cylinders and reservoir, and in the adoption of a sufficiently slow piston speed. The water jacket may consist simply of a tank well lagged externally, and sufficiently large to contain the air reservoir, the connecting pipes, and the cylinders; or, if preferred, the reservoir and the cylinders may be enclosed in independent jackets or tanks, it being merely necessary to take care that each jacket contains a sufficient supply of hot water to furnish the heat required of it during the run. It may, at first thought, be supposed that the quantity of water required to supply this heat would be so great as to render the plan proposed an impracticable one. So far from this being the case, however, the quantity required is remarkably small, as we shall show on a future occasion, when we treat of the question in greater detail, and we may remark here that for running a 6-ton car for 3 miles over a fair ordinary road, the quantity of hot water required for the jackets would be but about 20 gallons only, it being supposed that this quantity is renewed by a fresh supply at a temperature of 200 deg. or reheated, say, by blowing steam into it, at the commencement of each trip. In some cases where a stove is employed to warm the car, the heat from this stove could be turned to account for maintaining the temperature of the jacket water.

We have mentioned that, in addition to using hot-water jackets, it appears to us desirable that a slow piston speed should be adopted for compressed air engines, and we may explain briefly why we hold this opinion, an opinion which may, perhaps, be opposed to the experience of some who have worked such engines without jacketed cylinders. Let us, for instance, consider the case of an engine in which the air, stored up at a high pressure in a main reservoir, is led thence, through a reducing valve, to an intermediate receiver, in which it is maintained at a constant pressure, while from this receiver it passes to the cylinder, and is cut off in the latter at, say, one-third the stroke. In such an arrangement the work expended in the intermediate receiver in supplying air to the cylinder is balanced by that developed by the entrance of the air from the main reservoir, and under these circumstances the intermediate receiver is exposed to neither a loss nor gain of heat, so long as the air flowing into it from the main reservoir is maintained at a constant temperature. The work done during the first third of each stroke prior to the valve closing the admission port, is really done by the expansion of the air in the main reservoir, and it is to that reservoir, consequently, that the heat must be supplied if the air flowing to the cylinder is to be maintained at a constant temperature. With a hot-water jacket there need be no difficulty in adopting such a form of main reservoir as will enable this required amount of heat to be communicated to the contained air with certainty. After the point of cut-off is passed, however, the work done in the cylinder during each stroke is performed by the expansion of the air contained in the cylinder, and this expansion is, of course, accompanied by a refrigerating effect. To prevent the temperature of the air in the cylinder falling too low during this expansion, it is desirable to supply heat from external sources while that expansion is taking place. But air takes up heat but slowly from the surfaces with which it is in contact, and hence, that the heating to which we have referred may be sucessfully performed, it is necessary either to envelop the cylinder in a jacket of which the contents are kept at a high temperature, or to employ such a slow piston speed that time is given for the absorption of heat from a jacket of which the contents are but moderately heated. For several practical reasons we prefer the latter alternative, and hence it is that we advocate slow piston speeds for compressed air engines. What the best piston speed may be it is impossible at present to say, as data for arguing the question properly are wanting; but we consider that there is evidence available to show that this speed is much lower than has hitherto been generally adopted for such engines, and we believe that the matter is one which has not hitherto received the attention which its importance deserves. Air, it must be remembered, possesses very different qualities to steam, and the arguments in favor of high-piston speeds for steam engines certainly do not appply to motors worked by compressed air.

We have now directed attention to some of the leading points connected with the system of working engines by compressed air; but we have very far from exhausted the subject. There are said to be more ways of killing a dog than hanging him, and it is equally true that there are more ways of getting rid of the trouble arising from frozen moisture in the class of engines of which we have been speaking than that of jacketing the reservoir and cylinders. A consideration of these methods, however, we must leave for a future article, when we shall also have something to say of the system from a quantitative point of view; or, in other words, shall speak of the amount of compressed air which it is necessary to carry to perform a given amount of work, and shall probably treat of the efficiency of the system as a whole.

SOLAR HEAT.

By Captain JOHN ERICSSON.

From "Nature."

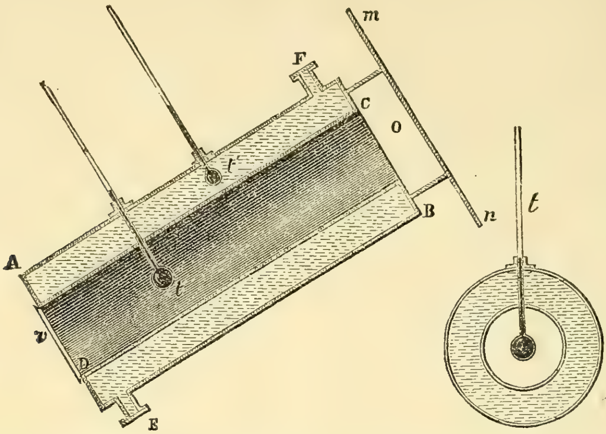
The calculations presented by Père Secchi, in his work "Le Soleil," relative to solar temperature and solar radiation, tending to discredit the result of recent investigations on the subject, I have carefully examined the "solar intensity apparatus," the indications of which form the basis of those calculations. This unique device will be found delineated on p. 267 of the work referred to, the accompanying illustration (Fig. 1) being a facsimile of the same. It represents a longitudinal section through the centre line, thus described:—A B and C D are two concentric cylinders soldered one to the other; they form a kind of boiler, the annular space being filled with water or oil at any temperature. A thermometer, *t*, passes through a tube, across the annular space, to the axis of the cylinder; it receives the solar rays introduced through a diaphragm, *m n*, the opening, *o*, of which is very little larger than the bulb of the thermometer. A thick glass, V, closes the back part of the instrument, and admits of ascertaining whether the thermometer is placed in a direct line with the pencil of rays. The interior cylinder and the thermometer *t* are coated with lamp black. A second thermometer, *t'*, shows the temperature of the annular space, and consequently that of the inclosure. The whole apparatus is mounted on a support having a parallactic movement, to facilitate following the diurnal motion of the sun. The apparatus being exposed to the sun, it will be found, on observing the two thermometers, that their difference of temperature increases gradually, and that in a short time it ends by being constant.

Before pointing out the peculiarities of the contrivance thus described by Père Secchi, it will be instructive to examine his "solar intensity apparatus," manufactured by Casella, represented in Fig. 2. The manufacturer publishes the following statement regarding this instrument:—"Two thermometers are here kept immersed in a fluid at any temperature, and a third surrounded by the same conditions, but not immersed, is exposed to the rays of the sun. The increase of temperature thus obtained is found to be the same, irrespective of the temperature of the fluid which surrounds it." No one acquainted with the principles which govern the transmission of heat within circulating fluids can fail to observe that the thermometers applied above the central tube wlll not furnish a reliable indication of the temperature of the fluid below the same, nor of any portion of the contents of the annular space towards the bottom. Apart from this defect, it will be perceived that an upward current of atmospheric air will sweep the underside of the external cylinder, causing a reduction of temperature of the fluid confined in the lower half of the annular space. Again, the heat radiated by the bulb of the thermometer exposed to the sun will elevate the temperature of the air within the central tube, and consequently produce an internal circulation tending to heat the upper part of the fluid contained in the annular space. The effect of the irregular heating and cooling thus adverted to will be considered after an examination of the result of some observations recorded in Table A, conducted at different times during the month of September 1871. In order to insure an accurate position, the instrument during these observations was mounted in a revolving observatory upon a table turning on declination axes provided with appropriate mechanism and declination circle. An actinometer being attached to the same table, the true intensity of the radiant heat, as well as the sun's zenith distance, were recorded simultaneously with the indications of the Secchi instrument furnished by Casella. Let us first consider the tabulated observations of September 2 recorded at equal intervals of three minutes. The indication of the two thermometers immersed in the fluid contained in the annular space first claims our attention, since the temperature of this fluid is the principal element in Père Secchi's computations of solar temperature. It will be seen on referring to the second and third columns of the table, that, while the upper thermometer indicates a mean temperature of 86.9 deg., the lower one shows only 79.5 deg., difference = 7.4 deg. This great discrepancy of temperature at different points of the upper portions of the annular space at which, owing to the inclined position of the concentric tubes, something like uniformity ought to exist, suggests a still greater discrepancy of temperature at the underside towards the lower termination of the tubes. In addition therefore to the observed irregularity of temperature at the upper part, shown by the table, no indication whatever is furnished of the temperature of the fluid in the annular space below the central tube, nor towards the termination at either side. Obviously, then, no accurate computation can be made of the degree of refrigeration to which the central thermometer is exposed by the radiation from the cold blackened surface of the internal tube, every part of which, as we have seen, possesses a different temperature compared with the rest, consequently transmitting radiant energy of different intensity. It will be found practically impossible, therefore, to determine the true differential temperature of the contents of the bulb exposed to the sun's rays and the fluid contained in the annular space. Hence, the differential temperature entered in the table, the result of comparing the indications of the thermometers, is manifestly incorrect. It will be found also by reference to the table that while the mean temperature imparted to the central thermometer by the sun's rays is 93.1 deg., the mean temperature of the fluid in the annular space is 83.3 deg. Consequently, the intensity of solar radiation established by the instrument is only 93.1 deg.—83.3 deg.= 9.79 deg Fahr. Now, the sun during the recorded experiment of September 2 was exceptionally clear, the mean indication of the actinometer while the experiment lasted being 60.05 deg., thus showing that the energy developed was only $\frac{9.79}{60.05}$= 0.16 of the true radiant intensity. The mean zenith distance, it may be mentioned, was only 33 deg. 24 min. during the experiment. Agreeable to the table of temperatures previously published, the maximum solar intensity for the stated zenith distance is 63.35 deg.; thus we find that the sun, as stated, was exceptionally clear while the trial took place, which resulted in developing the trifling intensity of 9.79 deg. Fahr. The result of the experiments conducted September 6th, recorded in the table, it will be seen was nearly the same as that just related, the mean temperature indicated by the thermometer exposed to the sun being 98.2 deg., while the mean of the two thermometers immersed in the fluid was 87.8 deg., hence the differential temperature 98.2 deg.—87.8 deg.=10.4 deg. The mean temperature of solar radiation during the experiment, ascertained by the actinometer, was 59.75, the zenith distance being 35 deg. 33 min. Consequently, the intensity indicated September 6th was only $\frac{10.45}{59.75}$= 0.17 of the true energy of the sun's radiant heat, against 0.16 during the previous experiment. It will be observed that the fluctuation of the differential temperature was much greater September 2d than during the succeeding experiment, owing, no doubt, to the influence of currents of air produced by a strong breeze on the first occasion, the revolving observatory being partially open on the side presented to the sun during observations.

With reference to the small differential temperature indicated by the Secchi instrument manufactured by Casella, it may be urged that it is not intended to show the true intensity of solar radiation on the earth's surface, but simply a means of determining solar temperature. Granted that such is the object, yet the extreme irregularity of the temperature of the fluid within the annular space shows that the instrument is unreliable, a fact established beyond contradiction by an experiment instituted September 27, 1871. On this occasion water of a uniform temperature was circulated through the annular space. This was effected by gradually charging this space from the top, and carrying off the waste at the bottom, holes having been drilled in the external casing for that purpose. The result of this conclusive experiment is recorded at the foot of Table A. It will be found on reference to the figures, that the mean difference of the two thermometers immersed in the fluid was only 64.9°-64.4=0 5°, while the mean differential temperature was augmented to 79.1°-64.45=14.65° against 9.79° on the 2d of September, although the zenith distance was greater, and the solar intensity less; circumstances which ought to have *diminished* the indicated intensity. It is needless to enter into any further discussion of the demerits of the instrument represented in Fig. 2. We may now return to the consideration of the device delineated in Fig. 1, copied from "Le Soleil." It will be seen that the material difference of construction is that of applying only one thermometer for ascertaining the temperature of the fluid in the annular space Possibly this single thermometer may indicate approximately the mean temperature of the upper and lower portions of the fluid above the central tube; but it furnishes no indication of the temperature below, nor at either extremity of the annular space. The inadequacy of the means adopted for ascertaining the temperature of the internal surface which radiates towards the bulb of the central thermometer having thus been pointed out, it will be well to consider whether the expedient of passing a stream of water of nearly uniform temperature through the annular space, will insure trustworthy indication. In order to determine this question, I have constructed two instruments, in strict accordance with the delineation in Fig. 1, excepting that in one of these the concentric cylinders are considerably enlarged; the annular space, however, remaining unchanged. Experiments with the two instruments prove that the enlargement does not materially influence the indications, provided water of a uniform temperature be circulated through the annular space. But these experiments have demonstrated that the size of the bulb of the thermometer exposed to the sun cannot be changed without influencing the differential temperature most materially. This will be seen by reference to Table B, which records the result of experiments with different thermometers, and tubes of different diameter, conducted October 17, 1871. As on previous occasions, the instruments, in order to insure accurate position, were attached to the declination table arranged within the revolving observatory. The bulbs of the thermometers employed were very nearly spherical, their diameters being respectively 0.30 and 0.58 in. The upper division of Table B, which records the experiment with the *small* bulb exposed to the sun, establishes, it will be seen, a differential temperature of 14.4 deg. for the instrument having the $1\frac{1}{4}$-in. central tube, and 16 deg. for the one having the 3-in. central tube. Referring to the lower division of the same table, it will be seen that when the thermometer with the *large* bulb is exposed to the sun, the differential temperature reaches 22.5 deg. in the instrument containing the $1\frac{1}{4}$-in. central tube, and 21.1 deg. in the one having the 3-in. tube. We thus find that, by doubling the diameter of the bulb of the thermometer exposed to the sun, all other things remaining unchanged, an augmentation of the differential temperature amounting to nearly one-third takes place. This fact proves the existence of inherent defects fatal to the device delineated in Fig. 1, rendering the same wholly unreliable.

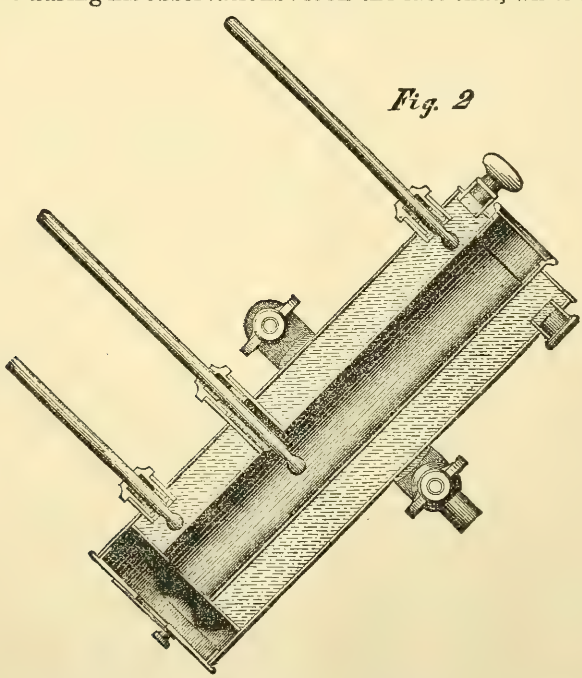
Agreeably to the doctrine of exchanges, the diameter of the bulb is an element of no moment, since the internal radiation towards the same—*provided its temperature be uniform*—depends solely on the temperature and annular distances of the radiating points of the enclosure. Infallibility of the "solar intensity apparatus" has evidently been taken for granted on the strength of the soundness of this doctrine, as we find no allusion to the size of

FIG. 1.



the bulb in M. Soret's account of his observations of solar intensity on Mont Blanc; nor does Mr. Waterston, who employed a similar instrument during his observations in India, advert to the dimensions of the bulb of the thermometer exposed to the sun. These physicists apparently overlook the fact that, while the entire convex

Fig. 2



area of the bulb is exposed to what may be considered the cold radiation from the enclosure, only one half receives radiant heat from the sun. This circumstance would be unimportant if the heat thus received were instantly transmitted to every part; but the bulb and its contents are slow conductors, while the conducting power diminishes nearly in the inverse ratio of the square of the depth. Consequently, by increasing the diameter, the parts of the bulb opposite to the sun will receive considerably less heat in a given time than if the diameter be diminished.

TABLE A, *showing the result of observations made with Secchi's "Solar Intensity Apparatus," manufactured by Casella.*

SEPTEMBER 2, 1871.

Thermometer exposed to the Sun.	External Casing.			Differential Temperature.	Zenith distance.
	Upper Thermometer.	Lower Thermometer.	Mean.		
Fahr.	Fahr.	Fahr.	Fahr.	Fahr.	° ′
83 5	76.0	70 0	73 0	10 5	33 0
84.2	77 0	71.5	74 2	10.0	
85 5	79 0	74 2	76.6	8.8	32 50
86 0	83 5	74.5	79.0	7 0	
89.0	84 0	75.5	79 7	9.2	33 0
90.5	85.0	76.5	80.7	9.2	
92.0	85.5	78.0	81.7	10 2	33 10
93.0	86.5	79.0	82 7	10 2	
94.0	87.8	80.0	83 9	10 1	33 21
94.5	89.0	81.5	85.2	9 2	
95.5	90 0	82 5	86 2	9.2	33 32
96.5	90.5	83.5	87.0	9 5	
98 0	91.5	84.5	88 0	10.0	33 44
99 0	92 0	85.0	88.5	10 5	
100.0	93.0	86.0	89 5	10.5	33 56
101.0	93.5	86.5	90.0	11.0	
101.5	94.0	87.0	90.5	11 0	34 8
93.1	86.9	79.5	83.3	9 79	33 24

SEPTEMBER 6, 1871.

94.5	88 0	81.5	84.7	9.7	35 56
95.5	88 5	83 0	85·7	9.7	
96 5	89 5	84.5	87 0	9.5	35 41
97.5	90 0	85 0	87 5	10.0	
98.0	90.0	85 0	87.5	10 5	35 26
98 5	90.5	85.5	88.0	10.5	
99 0	90 5	85.7	88.1	10.9	35 11
100.0	91.0	86 5	88.7	11.2	
100 3	91.0	87 0	89.0	11.3	34 56
100.3	91.2	87 5	89.3	11.0	
100.5	91.5	88.0	89 7	10.8	34 41
98 2	90.2	85 3	87.8	10.45	35 33

SEPTEMBER 27, 1871.

78.5	64 0	64 0	64.0	14.5	44.0
79 0	65.0	64.0	64 5	14 5	
79.5	65.0	64.5	64.7	14 7	44 55
79.5	63 0	65.0	64.0	15.5	
79.5	64 0	65.0	64 5	15.0	45 51
79.0	64.5	65.0	64.7	14.2	
79.0	64.5	65 5	65 0	14 0	46 48
79 0	64 5	65.5	65.0	14 0	
79.0	65.0	65.5	65 2	13.8	47 46
79.1	64.4	64.9	64.65	14.45	45 16

TABLE B, *showing the result of employing different thermometers.*

Diameter of bulb 0.30 in.

1¼-inch tube.			Zenith distance.	3-inch tube.			Zenith distance.
Sun.	Fluid.	Diff.		Sun.	Fluid.	Diff.	
Fahr.	Fahr.	Fahr.	° ′	Fahr	Fahr	Fahr.	° ′
74	60	14	50 32	77.5	62 1	15.4	49 54
74.5	60.3	14.2	50 24	78.5	62.3	16.2	50 3
75	60.7	14 3	50 16	79	62.5	16 5	50 12
75 5	61	14.4	50 8	79	63	16	50 21
76	61	15	50 1	79	63	16	50 30
75.0	60 6	14.4	50.16	78.6	62.6	16.0	50 12

Diameter of bulb 0.58 in.

1¼-inch tube.			Zenith distance.	3-inch tube.			Zenith distance.
Sun.	Fluid.	Diff.		Sun.	Fluid.	Diff.	
Fahr.	Fahr.	Fahr.	° ′	Fahr.	Fahr.	Fahr.	° ′
83.6	62.6	21	49 54	79 2	60.1	19 1	50 32
85.5	63	22.5	50 3	81	60.3	20.7	50 24
86.4	63.4	23	50 12	82 5	60.7	21.8	50 16
86.7	63.5	23 2	50 21	82.7	60 7	22	50 8
87.7	63.7	23	50 30	83	61	22	50 1
85 9	63.2	22.5	50 12	81.7	60.6	21.1	50 16

CARBONIZED SEWAGE.

From "Engineering."

All processes for the manufacture of sewage into poudrette may be classed under the above heading, although in some cases the process of carbonization is not carried so far as in others, and in only one of all these is any attempt made to utilize the gases thrown off from the sewage matter during the process of carbonization. This is known as "Hickey's system of conservancy by carbonization." Mr. Hickey is engaged in India, where the Government has so far taken up the question as to grant certain small sums for testing the efficacy of that gentleman's invention. The main features of Mr. Hickey's plan of utilizing sewage are that he collects the gases evolved during carbonization, which he proposes to make available for town illumination, whilst the poudrette or coke that remains has been found to be a most excellent deodorizer, and, mixed with the ammoniacal liquors collected from the gas retorts, it also forms a valuable manure. Such are the claims put forward by Mr. Hickey in favor of his invention, and, so far as it has hitherto been tested, the results would appear partially to justify the expectation that some considerable advantages may be expected to arise from its introduction. Whether it will ever be found practicable to illuminate our towns with gas manufactured from the contents of their respective sewers, is, we need scarcely say, very doubtful. The system of water-carriage for sewage is altogether opposed to the success of the carbonization process, in so far as its application for the manufacture of gas is concerned, in consequence of the large amount of fuel that would be required to drive off the water by evaporation before the other contents of the retort would begin to give out gas in any quantity. The destruction of sewage by fire is probably one of the oldest methods of disposing of it, and has been used in India.

The production of burning gas for lighting purposes, by the carbonization of ordure, is not, as is generally believed, a novelty, for so far back as 1686, a cerain savant named Dalsevius made experiments in Paris, and satisfactorily proved that an inflammable gas could be obtained by exposing organic matter to a very high temperature in hermetically closed vessels, and further, that an attempt was made at Paris in 1841 by Boussingault and Payen to prepare, by the carbonization of night refuse, an inodorous manure, and so far succeeded, that it was classed amongst the best of its kind, as in 1,000 parts, there were 29.6 of nitrogen, against 12.4 in ordure in its natural state, and this fertilizing constituent obtained for it a very remunerative commercial value. Since then, the carbonization of fecal matter has continued to be practised in France by Mr. Salmon, a distiguished chemist, who has rendered great service to hygiene by his discoveries, and the application of chemistry to the disposal of the carcases of dead animals and other organic matters in such a manner as to render them quite innocuous, and at the same time useful for industrial or agricultural purposes. Mr. Salmon's method of manufacturing poudrette or artifical guano, is to mix up the night-soil with a certain quantity of finely powdered charcoal, poudrette, or noir animalisé (such is the name given to the residue of the carbonization of night refuse), to deodorize the large quantities of fecal matter collected daily in his grounds. The mixture is afterwards put into hermetically closed iron cylinders and carbonized, and the gas escaping from the cylinders is turned to account by being introduced into the furnace; and the burning of the gas, it is said, considerably reduces the consumption of fuel.

In order to utilize the gases given off by heat, as well as to preserve the charred residuum, which is thus proved to be effective not only as a deodorizer, but it is also valuable commercially for agricultural purposes, special appliances are required, the provision of which, as well as the expense of fuel, establishment, etc., must be taken into consideration in estimating the financial results of this method of disposing of town sewage. The desire to make the disposal of sewage absolutely remunerative to the community is, we think, a mistake, for whatever means may be adopted with that view, the one great end undoubtedly is to remove what would otherwise become a nuisance, and it is therefore a convenience which may justly be expected to have to be paid for. But whilst that is the case, the sewage itself has undoubtedly a commercial value, and it should not therefore be allowed to run to waste, but be converted, by whatever process may appear must suitable under the circumstances of each case, provided the process of such conversion does not greatly exceed in cost the price at which the product realized can be sold for.

There are many who are opposed, on sanitary grounds, to water-carriage for sewage in tropical countries, owing to the more rapid decomposition and consequent emanation of sewer gases which takes place in hot climates than where the temperature is more moderate. This question is now undergoing a practical test in several of the largest cities in India, where a regular system of sewers and water supply renders the adoption of water-carriage practicable. At the same time other methods of disposing of town sewage are being tested. The dry earth system of conservancy has been in use in the Madras Presidency since the latter part of 1863, and it has also been adopted in other parts of India in barracks, hospitals, and prisons. Mr. Hickey's plan of conservancy by carbonization is a more modern introduction, and can hardly at present be considered to have advanced beyond the experimental stage; but so far as it has been already tested, it would appear to offer advantages to a country like India, superior to that of water-carriage in every respect excepting one, and that is the conveyance of all the sewage of a town to one place of outfall. Experiments recently made in India on a small scale, where the excreta of sixteen men for one day was treated in a small experimental gas-making apparatus, proved that the proposed process of converting such matters into gas and coke was perfectly practicable, and easy. In estimating the cost of the process from the results obtained by this experiment, it was calculated that the cost of coal for evaporation of the liquid portion of the sewage, and the subsequent carbonization of the solids, would be at the rate of four rupees per thousand of population per day, in addition to whichmust be added the expense of first cost and wear and tear of machinery, as well as the cost of labor required in the manufacture. The total amount of gas per thousand of population, raised to a temperature of 870 deg. Fahrenheit, was equal to 1156 cubic ft., which when made to burn while issuing under pressure from a large orifice, gave a flame which appeared to diffuse a considerable amount of light; but when tested by an ordinary burner, the light was pale and feeble. When tested in a photometer its illuminating power was found to be only equal to 2½ candles. Tested against the ordinary gas burnt in Calcutta, its value was only one rupee four annas per thousand cubic ft., representing a total value of one rupee seven annas (three shillings nearly) per thousand of population. The amount of charcoal remaining in the retort per thousand, weighed, when quite dry, 39 lbs., valued at about one shilling. In addition to the above, there is also nearly 2 lbs. by weight of ammonia yielded by the same quantity of refuse. The charcoal contains more than half its weight of ash, and is therefore useless as a heating agent. According to the above calculation the value of the products would appear to be about four shillings per thousand head of population per diem, and the cost of producing them eight shillings for coals alone. An analysis of the gas produced shows it to consist of the following:

Hydrogen	35.36
Marsh gas	31.28
Olefiant gas and other heavy hydrocarbons	2.40
Carbonic oxide	21.74
Carbonic acid	9.00
Phosphoretted hydrogen, a trace, say	0.22
	100.00

The poudrette remaining after making the gas, appears to be better suited than ordinary earth for carrying out Moule's system of dry conservancy; for whilst dry earth has the power of absorbing from 30 to 35 per cent. of moisture, the poudrette absorbs, under similar circumstances, 100 per cent., so that while 8 lbs. per head per diem of the former are required to carry out Moule's system, only about 2¼ lbs. per head per diem would be required of the poudrette to carry out a modification of Moule's system, which, whilst being equally efficacious, would be much less expensive. Any amount of poudrette in excess of what might be required for the above purpose would, when mixed with the ammonia obtained during this process, form a most valuable manure.

THE EMERALD MINES OF MUZO.

From "Journal of the Society of Arts."

The past history and present condition of the enerald mines of Muzo, which are situated in the State of Boyaca, four easy days' journey from the capital, derive considerable interest from the fact that, with the exception of the East Indies, the emerald can only be found at Muzo. Mr. Bunch, secretary of legation at Bogota, has obtained most of the information contained in his notice of the subject from his French colleagues, who would naturally be in communication with the French company now in possession of the mines. According to a law recently passed by the Columbian Congress, the present strict monopoly, under which these mines are held by the Government, will cease in 1874, at the expiration of existing agreements, when it will be free for any one to work them.

From certain indications, apparent to persons residing upon the spot and acquainted with the country, it is evident that the mines of Muzo were known long before the discovery of America and the conquest of Granada by the Spaniards. When an expedition came in the year 1553, under the orders of Don Juan de Lancheros, to reduce the tribe called "Los Muzos" to the Spanish rule, these Indians were found to possess a large quantity of emeralds. How they worked the mines it is not easy to understand, as they had no tools of iron. It is supposed that they had found the stones in the bed of the mountain torrent, for it sometimes happens that the winter rains produce great land slides, which lay bare large veins of emeralds, the stones in which are washed out by the waters. But these gems are of a very inferior quality; they resemble those which are still found in the Indian burial places, or in the lakes into which the Indians used to throw their riches during their contests with the Spaniards. However this may have been, the mines of Muzo were worked soon after the arrival of the Spaniards, on a large scale, both in the open air and by means of subterranean galleries; but about the middle of the eighteenth century the labors were abandoned, no one knows why. The old people of the district relate that their fathers used to work at the mines until the mountains vomited flames, which lasted for many years, and made it impossible to go on. This tradition resembles a fable, especially as there are no signs of a volcanic eruption near Muzo. It is, therefore, impossible to say why the labors were interrupted. Not until after the War of Independence and the expulsion of the Spaniards, were they resumed, when the Republic took possession of the mines, and let them out to individuals and to companies.

About the year 1844, a Columbian, named Paris, carried a large quantity of emeralds to Europe and the United States, many of which he sold for considerable prices. In order to disarm hostility at home, he presented to the city of Bogota various valuable objects, such as a fine bronze statue of Bolivar, cast by Tenerani, of Rome, a clock for the cathedral, instruments for the observatory, etc. He died a rich man. In 1864, a French company obtained a grant of the mines for ten years, for an annual payment of $14,700 (about £3,000), together with a monopoly of all emeralds in Columbia, the Government binding itself to prohibit the working of any other mines which might exist in the territory of the Union. This company is now in possession of Muzo, where the works are directed by a French engineer, named Lehmann. In the opinion of this gentleman, the mountains of Muzo are rich in emeralds, the quantity hitherto extracted being almost inappreciable. The principal mine now worked is pierced in every direction by galleries made by the Spaniards. Since 1825 it has been worked in the open air; an immense number of gems have been found, many of them of great value. After this mine shall have been exhausted, which will not be for many years, not a thousandth part of the ground containing emeralds will have been touched. This consists of a chain of mountains which extends beyond human sight. At two days' journey from Muzo, there is another mine, called "Lasquez," which was just touched by the Spaniards, and is evidently very rich. All this ground, including Lasquez, bears traces of the presence of the Spaniards; and, as the geological formation is the same in the whole neighborhood, it is clear that the day is very far distant when these mountains shall be exhausted; in fact, they may be said to be inexhaustible.

The mountains of Muzo, like those of the whole central Cordillera of the Andes, belong to the lower formation of chalk. If the structure be observed of one of the portions now worked, the emeralds will be found in two distinct layers,—the first, or upper one composed of a calcareous bitumen, which is black and friable; the second, lower down, also of calcareous bitumen, but hard and compact. These two layers are generally separated from each other by a distance of from seventeen to twenty-two yards. In the upper layer are found the veins which yield the "nests" of emeralds, that is to say, a number of these gems massed together. But after one of these nests the vein disappears, being crossed by others of a different kind, which run in a different direction to those containing the emeralds. These latter veins are called "cenicerous," from their ash-color. They are generally horizontal, whilst the emerald veins are perpendicular; they all run from north-east to south-west. The veins of the lower layer are more regular, and are followed for fifty or sixty yards, and even more. "Nests" of emeralds are very seldom found in them, but they are more easy of extraction. When veins of fluor-spar, well crystallized, are met with, the emerald is not far off; the presence of rock crystal is also a good sign, as likewise that of a pretty pyramidal shape, of the color of honey, called "parisite."

The mine of Muzo is worked both by

galleries and in the open air; the latter method, although more expensive, is more profitable, in consequence of the great irregularity of the veins, which are thus more easily got at. All the emeralds now extracted are sent to Paris, where they are cut, an operation which causes them to lose more or less of their size and weight, according to the degree of crystallization and of purity. Of late years, too, this gem had obtained a fictitious value in France, on account of the color, green being that of the Empire. They were much in demand at the Imperial Court. It is impossible to determine the number of carats anually taken from the mines of Muzo. The production is very variable, depending upon the number of veins which may be found, and their richness. Whole months may pass without a single emerald being found, whilst 100,000 carats may be procured in a few days. It is also impossible to fix the mean value of the carat of emerald, as, when the stone is large, of a very dark color, and perfectly pure, which latter condition is extremely rare, it may be worked up to about £20 sterling a carat, whilst stones of a bright color, full of flaws, and divided into small fragments, are not worth 5s. a carat. These are called "Morallos," and have scarcely any value. There are no means of ascertaining the mean annual quantity of emeralds which has been previously or is now procured. This is the company's secret, which it preserves, from fear of the competition which will arise when it applies to Governmemt for a renewal of its lease. It is, however, estimated that, notwithstanding the expense of working, its financial condition is prosperous, and every one believes it will endeavor, in 1874, to secure that renewal. But there is no chance of the monopoly being preserved, since the present system is prejudicial to the treasury, as there are many mines which might be worked with profit, but which cannot be touched as matters stand. Without doubt, any great increase in the number of emeralds brought into the market would tend to lower that price; but it seems highly probable that English capital might hereafter be successfully employed in this branch of industry.

ON SOME NEW BUILDING MATERIALS.

From "The Engineer."

To make planks out of sawdust has hitherto been regarded a problem so insoluble that the expression has been used to point a jest, and referred to the same category as that to which belongs the art of spinning ropes out of sand. However, like so many other so-called impossible things, the manufacture of planks out of sawdust is now unquestionably possible, though we do not say economical; still the operation by which this might be accomplished, slightly varied, yields products not only curious but economical, and some of them, we believe, are destined to find large application as building materials.

Let us explain. The chemical material lignine, or cellulose, was regarded until quite recently as insoluble. Practically, everybody knows that timber of whatever species may be exposed to water for any length of time without suffering the slightest amount of loss by solution. Timber thus exposed may or may not decay—that will depend on the sort of timber, and also on the agents held in solution by the water of immersion ; but it never dissolves. A more striking illustration, however, of the non-solubility of lignine or cellulose is seen in the long durability of cotton and linen goods. These may go to the wash again and again ; when at the wash they have to suffer from one or more of the various nostrums which washerwomen delight in—alkali, plain or caustic, chloride of lime, soaps in variety. They have to withstand rubbing, boiling, ironing, mangling, and other hard usage; but the fabrics thus tortured never dissolve. They abrade and wear out mechanically, but that is all. The point need not be insisted on here, that every remark made concerning the non-solubility of woody matter, whether in the state of timber or of cotton and linen woven fabrics, equally applies to paper, which latter, although easily destructible by water soakage, is in water quite insoluble. Water can reduce paper to pulp, but that is all.

Having premised these remarks, we now come to the point of stating that the fluid "*cupro ammonium*" dissolves woody fibre with great facility. The rapidity of solution varies with the mechanical structure of the woody matter (cellulose or lignine) operated on. Old linen or old cotton textures that have suffered much wear and often gone to the wash dissolves in cupro ammonium, so to speak, immediately ; or, if a simile be required, they dissolve with very near the rapidity of a lump of sugar in a tumbler of hot water. New linen or new cotton are slightly more refractory, but still they dissolve with time. Similarly, and by a futher application of the same principle, sawdust, no matter of what wood, yields with more or less ease to this curious solvent.

There is good reason for belief that materials built up by taking advantage of this curious solvent property of cupro ammonium will before long be turned to great practical use, not, however, by effecting complete solution, but only partial or surface solution. Thus, to take a simple case, supposing it were desired to render a sheet of paper waterproof by cupro ammonium treatment, this could easily be effected in the following manner:—The sheet being dipped momentarily in cupro ammonium, and then passed between rolls to squeeze out excess of moisture, and finally dried, the paper so treated would be in a chemical, though not in a mechanical sense, waterproof. To be precise, such paper might be soaked indefinitely in water, even boiling water, without suffering any disintegration. Neither, if made into a bag and filled with water, would paper thus prepared allow any water to come through, save and except through such apertures as paper, even the best of paper, invariably possesses. Hence, to treat a single thickness of paper with cupro ammonium for the sake of waterproofing it, is an operation of very little use ; but if two thicknesses of paper be momentarily dipped in a cupro ammonium bath, then withdrawn and passed face to face between steel rollers, then the two surfaces adhere so absolutely that, when the compound material has dried, the plane of juncture is not only invisible, but cannot be rendered visible by any sort of dissection. Except under the condition that two holes in the two opposed sheets absolutely correspond, no defect of continuity can arise, and the chances against such correspondence of holes are almost infinite.

The manufacture of this double tissue paper furnishes the simplest case of what may be called lignine construction. What can be effected on two sheets can obviously be effected on any number by reduplication of the process, and thus artificial lignine sheets may be built up of any thickness, from that of paper to that of plank or scantling, should the operator so desire. The material, when in a certain state of moisture, moulds with almost the same facility as potters' clay. It readily corrugates, either by fluted rolling or by rectangular pressure, and the corrugated material, extremely light, hard and, chemically, next to indestructible, is destined, we believe, to supplant corrugated iron in numerous applications of the latter. So far as experience has gone, water exercises positively no influence on compound fabrics built up of lignine consolidated by cupro ammonium. Acids affect them only slightly, and not injuriously; in fact, the only agent which they cannot stand is ammonia.

With regard to cohesion, it is a remarkable, though not an unprecedented fact, that although cupro ammonium speedily effects solution of lignine, yet the first result of immersion is a strengthing of the fibre. If, for example, a piece of linen be tested for cohesive strength, and the result noted; if, then, a corresponding piece be dipped for an instant in cupro ammonium solution, next withdrawn, dried, and tested for cohesive force, this will always be found greater than before treatment. This result appears to be due to a contraction of the tissue by the chemical action, and suggests comparison with the curious accession of strength imparted to paper by instantaneous dipping in concentrated sulphuric acid, although a more prolonged immersion dissolves the same paper absolutely. The fact is very generally known that woody fibre—chemically speaking, lignine or cellulose—differs remarkably in cohesive tenacity, though all specimens of cellulose or lignine are identical as to chemical composition. If complete solution of any of these specimens be effected, the dried result is simply brittle semi-transparent glaze, the cohesion of which is no greater for the strongest original sample dissolved than for the weakest. In point of fact, it is in no case practically desirable to effect complete solution, but only an incipient surface solution, whereby the original fibres, retaining their form and mutual arrangement, may become cemented together. Bearing this circumstance in mind, fabrics of extraordinary tensile and cohesive strength may be prepared by alternating canvas with paper, or, if preferred, attaching breadths of canvas face to face immediately. Thickness for thickness, we do not think that any timber can equal the strength of these compound fabrics.

For building uses there can be little doubt of the numerous applications these curious fabrics are destined to command. Thus, for roofage the very thinnest double tissue paper would not merely be water but wind-tight; and but for providing against the casualty of snow and other extraneous weight, nothing would be gained by using a thicker material. We have however, seen a specimen made of six thicknesses of common brown paper, and corrugated, which seems to us to be stout, strong, and reliable enough to be proof against all ordinary casualties. As regards ornamentation, it is worthy of note that the natural tint of some of these cupro ammonium lignine structures is very elegant. They readily take any sort of paint; but if painting be had recourse to they should previously be sized, otherwise the oil absorption effects an undesirable softening.

Although these remarks have been specially directed to the building applications of cupro ammonium fabrics, yet consideration of their properties will suggest many other utilities. Amongst these the manufacture of tubing is very important. A cheap, indestructible, and absolutely waterproof paper tube admits of more applications than can be summarily indicated. Amongst these the manufacture of cartridges for breech-loading arms and mining purposes stands prominent. Possibly thin sheets of this material may be turned to good account in hat-making —probably in boot-making. We have even seen a waterproof paper cape, the only obvious defect of which is a trifle too much of rigidity.

THE CHANNEL FERRY.

From "Engineering."

Simultaneously with the independent action of the French Government in the matter of International Communication, Mr. John Fowler's scheme for a Channel Ferry is again brought before the public, and is likely this year to receive more serious consideration than it has hitherto done. It is now seven years since a practical scheme to establish a service of steamers on a grand scale for the conveyance of passengers and goods between Dover and Calais was first made, and since that time the main features of the project have remained unchanged, although details have necessarily been altered.

After going through the usual preliminary delays, the Bill for the International Communication was passed in 1870, in the face of much opposition, and had it not been for the unfortunate complications on the Continent, which suddenly put an end to protracted negotiations, patiently followed through a host of difficulties up to a successful point, the works at Dover, as well as those on the French coast, would before now have been commenced. During the continuance of the war, however, and for many months after its conclusion, nothing could be done in the matter, at least with the co-operation of France, and it was therefore allowed to rest until a more favorable time.

In many respects it is well that this delay took place, because the project sanctioned in 1870 comprised a different arrangement of harbor at Dover to that orginally contemplated, and now proposed. The promoters of the scheme contemplated the construction of an independent harbor, owing to the opposition of the Dover municipality, but they have so far modified their scheme that at present they propose only to extend the Admiralty pier, and to construct a new pier, 4,000 ft. in length, together with a breakwater. By carrying out this plan the cost of works will be reduced, and the time required for construction will be diminished. Moreover, the Dover Harbor Board, which was the principal opponent to the passing of the bill in 1870, will greatly benefit by the alteration.

At a recent meeting of the Dover Town Council Mr. Abernethy, in the absence of Mr. Fowler, stated that there were two main considerations. "First, the engineers had resolved to have no half measures, but to carry out a plan which would not require, as any half measures probably would, to be enlarged and altered hereafter, at loss of time, additional expense, and at the cost of hampering and hindering the development of the great traffic anticipated; secondly, it was desirable, in their opinion, for the commercial success of this undertaking, that provision should be made for carrying the trains across the Channel upon the steamers, so as to afford to passengers an unbroken through-train communication to Paris, and also that the same accommodation might be provided for goods."

With regard to the first of these considerations, there can exist no difference of opinion; the comparatively insignificant saving in first outlay would form no equivalent for the imperfection in the service that would necessarily follow; and the subsequent cost for the amplification or completion of the works would probably be greater in the end. Upon the second point, however, considerable misconception and difference of opinion exist, and it is upon this point that the Channel Ferry scheme is generally attacked.

While it is universally admitted that the present service falls short of the requirements of the existing traffic, and is, in fact, miserably deficient in comfort and facilities for passengers, it is urged that the proposition to effect an unbroken train communication between this country and the Continent is a useless refinement; and that the effects of motion, which it is not pretended could be entirely obviated by the adoption of the large boats, would be far more unpleasant to passengers sitting in railway carriages than to the same passengers in state-rooms. This statement is very true, but what of it? It is not proposed that the passengers should be shut up in their carriages; on the contrary, ample accommodation will be provided for them on board. The transfer of the carriages upon the vessel is an incidental advantage to the scheme, not a leading feature. The large boats Mr. Fowler has designed—450 ft. long and 57 ft. beam—are necessary for overcoming the heavy motion which the Channel seas impart to the smaller vessels, and the use of these large boats is the characteristic feature of Mr. Fowler's scheme—a feature that stamps its originality. No less are they necessary for receiving the goods wagons, which will be transferred from the railways to the rails laid in the lower part of the vessel, just as the passenger carriages are run upon its deck. Thus, to accommodate the goods traffic, and to obtain steadiness at sea for the benefit of the passengers, such vessels as the ones proposed (and to the efficiency of which Mr. Reed, Mr. Laird, Mr. Penn, and other well-known naval engineers have testified) are equally required.

Between the rows of saloons and state-rooms provided for the accommodation of passengers, there will be a wide space clear from end to end of the ferry, and it is rightly considered that this space could not be more appropriately utilized than by the passenger carriages, which will take comparatively little room, and add scarcely anything to the load of the boat. Thus the transfer of the train forms a natural part of the entire scheme, and nothing has been strained to achieve it. Had it presented any difficulties, could it only have been attained by a sacrifice of other requirements, or by a great increase in first cost, this part of the undertaking would never have been seriously considered. All travellers will fully appreciate the advantages arising from an unbroken railway communication with the Continent, and most would be willing to pay for the privilege of maintaining their carriage throughout were any charge demanded.

The inconvenience of shifting from the train to the boat at Dover, and going through the reverse operation on the French side, burdened with all the minor *impedimenta* of a journey, are too well known and appreciated to be enlarged upon, and we think that the travelling public can have but one opinion on this point. Mr. Fowler will save all this inconvenience by transferring the train, and although neither he nor any one can altogether arrest the evils of sea-sickness, his large boats will reduce it, and the more sensitive who succumb even under the modified condition of things, will at last be spared the infliction of climbing the wet and slippery steps of the Calais jetties, and can retreat to their carriage so soon as the smooth water of the harbor gives them confidence to quit their state-rooms.

It is urged that insurmountable difficulties will be encountered during bad weather in running the trains upon the ferry,* and in securing them afterwards. We think that a sufficient answer to these objections is supplied by the fact that Mr. Fowler has pronounced all the details of the undertaking to be practicable, and, indeed, easy. It is certain that experience will before many years settle these and all other points connected with the Channel Ferry, for the works connected with it cannot be much longer delayed. Public opinion becomes more and more decided against a continuance of the present unsatisfactory mode of transit, and money will be plentifully subscribed towards the completion of such a national work.

THE GRADIENTER.

By BENJ. SMITH LYMAN.

Written for Van Nostrand's Magazine.

Having seen in the last number of your excellent magazine, a very favorable account of the Gradienter and its use, I beg to point out what seems to me to be some serious defects of the method as compared with common vertical circle levelling.

In the first place the "percentage screw," the main feature of the instrument, is liable to wear, so that after some use it can be turned to a notable amount without moving the telescope, and so leads to a wrong reading.

In the next place, the friction and weight of the telescope and its axis give so much resistance to the percentage screw, as to strain it more or less, and tend to make its readings slightly inexact.

The error from these two sources might very well amount to so small a quantity as half a minute of arc or even a whole minute ; and it is not therefore suprising that, even "in testing the instrument" while it must have been comparatively new, "at a distance of 500 ft. the elevations as determined by the percentage screw would," sometimes though "seldom vary more than an inch from true levels." In a transit with a vertical circle or arc of a radius of two inches and a half or three inches, the vernier marks single minutes and it is very easy to read to half a minute. The sine of half a minute of vertical arc at a distance of 500 ft., is at most but nine-tenths of an inch. As the truth cannot be more than half way from the nearest possible reading to the next, not more, that is, than a quarter of a minute from the actual reading, the greatest possible error from this source is less than half an inch of level in a distance 500ft. It is clear, then, that the common vertical circle is much more exact than the percentage screw.

The vertical circle is also used far more conveniently and rapidly. It is claimed that the gradienter enables the reading of heights of 40 or 50 ft. above the level, which at a distance of 500 ft. would be a vertical angle of only thirty-five minutes; while we have just seen that the vertical circle can be used without lessening its exactness through any arc. Indeed the increase of the length of the sine of angles is so regular even up to forty-five deg., that graduations could be made if desired, so as to read direct with a vernier the height for 100 ft. of distance, and the number of feet above or below level could then be got by multiplication, as in using the gradienter. But it is perhaps more convenient to add the logarithm of the sine of the vertical angle to the logarithm of the number of feet of distance and so find the difference of level.

Moreover, the vertical circle requires no special adjustment at each station, answering to the adjustment of the zero of the percentage screw to the zero of its scale ; a saving of one source of care and error that is not unimportant.

With the vertical circle, too, the telescope can just as well be sighted at a target, of one height always (say about that of the telescope), and then there is no need of the many additions and subtractions that are described for the most convenient use of the percentage screw, and that lead to confusion and mistakes.

If, then, the gradienter is convenient and quick, how much more so must the common vertical circle be. It is needless to speak here particularly of the skilful work and great care that must be laid out to make the percentage screw properly; and all to no purpose it seems.

Perhaps the commonest source of error in using thr vertical circle is gross misreading, especially reading the wrong way from a numbered graduation or from the zero; for example, reading twelve deg. instead of eight, or mistaking up one deg. when ten is marked for down one deg. Such mistakes come of course from having the numbering made in one direction for a rising angle and the other way for a falling one; and they could be done away with by having a continuous numbering for both angles, so that the reading should always be in one direction. For instance let the reading for a level sight be zero; for ten deg. rise, 350 deg.; and for ten deg. fall, 10 deg.; or take the numbers either side of 180 deg. The sines of the angles would be the same as in the common graduation; and no special additional mark in the note book would be needed to show whether the sight is a rising or falling one. There is plainly the same motive for having but one continuous graduation from zero to 360 deg. on the main plate and compass ring, and it is well arranged so on the gradienter. Having the numbers run different ways in different quadrants is a most fruitful source of error.

The use of the stadia as described with the gradienter, is doubtless a great saving of labor and time, and even a great gain in exactness over common chaining. But instead of having a rod graduated expressly for the stadia wires, it is much more convenient to have the wires adjustable by the surveyor, or adjusted by the maker so that they cut off a foot on the rod at a 100 ft. away, and the distance can be read direct from a level rod (marked in feet and hundredths), with the same sight as for the level or for the vertical angle. The eye piece of the new transit of Messrs. Heller & Brightly, of Philadelphia, is remarkably well suited from the flatness of its field, for stadia measurement.

THE EFFLUX OF ELASTIC FLUIDS.

From "Engineering."

Numerous experiments have been made from time to time since the days of Galileo for the purpose of determining the laws governing the flow of elastic fluids. During this lengthened period it has been very generally thought, and is still largely considered at the present time, that the same laws govern the flow both of elastic and inelastic fluids. We are aware that there have been experimenters, some of them able men, who have occasionally startled us by boldly announcing, as the results of experiments, theories totally different and opposed to that generally accepted. Some years ago an experimenter announced a theory to the effect that elastic fluids under a great or small heat of pressure could not flow into a vacuum. Another experimenter advocated a similar theory in France. More recently an experimenter declares and maintains that the velocity of efflux is the same whatever may be the recipient pressure, so long as the latter is less than half that constituting the head of pressure. So that atmospheric air at a pressure of 15 lbs. on the sq. in. would flow with the same velocity into a vacuum as into a recipient pressure equal to, or less than, 7½ lbs. on the sq. in. These, amongst other examples of a similar character, show the difficulties in finding a method of experimenting with elastic fluids under heads of pressure sufficiently great to be of a use in practice, and which is either free from those well-known changes which take place, due to the relations existing between the densities, temperatures, pressures, and volumes of elastic fluids in movement, or by which their effects can be accurately taken into account.

The greatest number of the experiments most relied upon have, however, been made on the efflux of elastic fluids under small heads of pressure, varying up to about 6 in. of water, and it is mainly the results of such experiments which have induced many scientific men to believe that elastic and inelastic fluids are governed by the same laws in their flow.

The laws affecting the flows of elastic fluids are of very great importance both to engineers and physicists. Every steam or other heat engine from the fire-bars to the flue or chimney in one direction, and from the boiler to the condenser in the other, consists of little more than numerous passages for the flow of elastic fluids of various densities and temperatures, and hence the importance of knowing the true laws which govern the flow of these fluids. The ventilation of mines, blast, and regenerative furnaces, the elastic fluids evolved from exploded gunpowder in guns, and from other explosive compounds used for various purposes, are, also, important matters depending on the laws of the flow of elastic fluids for a proper solution of effects. Considered purely in a physical sense, this question is not of less importance. During the last few years many earnest laborers have greatly extended our knowledge—as they are still doing—in connection with the elastic fluids composing the atmosphere of the sun, and the effects of their movements in causing the various phenomena which have recently been observed. The atomic action of matter is at present totally unknown, and it is more than probable that the first gleamings leading to a solution of that mystery will be through the action of matter in an elastic state.

Under these circumstances we have great pleasure in informing our readers that some extensive experiments and researches on the efflux of elastic fluids have recently been made by Mr. George Wilson, C. E., of Parliament street, Westminster; that the results of these experiments have been arranged for publication in a form suitable for the use of practical men, and that the results thus arranged will appear in this journal.

These experiments, which have been carried out on both air and steam, have been made by Mr. Wilson by three different methods and apparatus. The heads of the pressures of efflux commence as low as two-tenths of an inch of water, and are increased by fractions up to 1 in. of water, and then by consecutive inches up to 14 in. of water. The heads of pressure of efflux then commence at 1 in. of mercury, and are increased by consecutive inches up to 24 in. of mercury, and finally by degrees up to 100 lbs. on the sq. in. There is, thus, a gradual increase in the heads of pressure of efflux from that equal to two-tenths of an inch of water up to 100 lbs. on the sq. in. The efflux orifices consist of short tubes, one, two, and three centrimetres in diameter, altered for different series of experiments until they finally had the form of the contracted vein. A series of experiments have also been made with the same apparatus and efflux tubes with water for the purpose of comparison. It will be seen that these experiments have been made on that extensive scale which has so long been needed to show effectually the laws of efflux under different heads of pressure.

The important results which have been derived from these experiments, induced Mr. Wilson to extend his researches and examine all those made by various experimenters on the efflux of elastic fluids during the last 200 years, for the purpose of ascertaining the accuracy or defects of their methods of operating. Many of such experiments are published in the "Transactions" of the literary societies in England and on the Continent, and are consequently not easy of access to many persons, nor are they generally known. We hope to be enabled to place before our readers these valuable researches of Mr. Wilson at some future time.

As the period of the Transit of Venus in 1874 approaches, astronomers both at home and abroad are becoming more and more active in their preparations; and the American committee on this subject, it is understood, has already decided in considerable part upon the stations to be occupied. In Russia, the committee, under Prof. Struve, proposes the establishment of a chain of observers, at positions 100 miles apart, along the region comprised between Kamschatka and the Black Sea. The German committee has decided on recommending the organization of four stations for heliometric observations of the planet during its transit, one of them in Japan or China, and the others probably at Mauritius, Kerguelen, and Auckland Islands.

NARROW GAUGE vs. WIDE GAUGE.

By C. J. QUETIL, C. E., Principal Assist. Eng. Texas Pacific R. R.

Written for Van Nostrand's Magazine.

I have been directed by Gen. Geo. P. Buell, Chief Engineer of the Texas Pacific Railroad, to prepare an answer to Mr. Silas Seymour's attack on his (Gen. Buell's) late report to the Directors of the road, his official duties allowing no time for the performance of such a work.

I feel much honored by the confidence thus reposed in me by the Chief Engineer, and have tried to prove worthy of it.

The following article was prepared some time since and was submitted to Gen. Buell for approval. With his permission it is offered for publication.

The article is not prepared with the intention of influencing in any way the Directors of the Texas Pacific Railroad. The Legislature of Texas have decided that for that State the gauge shall not be less than 4 ft. 8½ in., and so far as my knowledge extends, the decision was made before Mr. Marshall O. Roberts requested of Mr. Seymour his opinion on the subject of the gauges.

The object of the following is merely to answer the attacks of Mr. Seymour on Gen. Buell's report.

The work would doubtless have been better performed by Gen. Buell himself, but new duties, as General in the army, demanded his attention, and the honor and duty of the reply was assigned to me.

It is not necessary, in comparing the cost of a wide-gauge road-bed with that of a narrow gauge, to observe the conditions indicated by Mr. Silas Seymour, in his pamphlet (p. 7).

Let us suppose that the average height of embankments of the two roads is 6 ft. and let us compare the sections of embankments of the two roads, one built for the 4 ft. 8½ in. gauge, the other for the 3 ft. or 3 ft. 6 in. gauge.

This will allow us to make a fair estimate of the cost of earthwork.

Let us first state that in making his report, Gen. Buell has compared the section of a road-bed embankment 14 ft. wide at top, as they are generally built for the 4 ft. 8½ in. gauge, with that of an embankment 9 ft. wide at top, corresponding to a narrow-gauge road.

Gen. Buell never pretended to establish or prove that a road built with 10 ft. 9½ in. width of embankment, or even with 10 ft. width of embankment, would cost 30 per cent. less than a wide-gauge road-bed, and Mr. S., in his review, does not compare the same sections of embankment as Gen. Buell has compared, and, naturally enough, he comes to a different result.

I am going to prove that Gen. Buell's assertions are right, not only for the economy of earthwork in favor of the narrow gauge, but also for the clearing and grubbing, hauling, drain boxes, culverts, bridges, superstructure, economy of dead weight in cars, and in fact all the points indicated in Gen. Buell's report.

I shall not assume, like Mr. S., that the width of bank of wide-gauge roads (4 ft. 8½ in.) which is generally 14 ft., might be 12 ft., but I will take it, as it is, at 14 ft., and in my answer to Mr. S. I will not compare what might exist in wide-gauge roads with what exists or might exist on narrow-gauge roads, but I will compare what actually exists on one system of road with what exists on the other, and in doing so, if I do not convert people to the narrow-gauge theory, but simply point to possible reforms in road-bed, and in cars, that might be made on wide-gauge roads, my work will not have been made in vain.

Let us compare the section of road-bed 6 ft. high with 1½ to 1 slope, and one of them 14 ft. wide at top, while the other is only 9 ft. wide at top.

The banks will have bottom widths of 32 ft. and 27 ft., respectively.

The difference between the two sections is 30 sq. ft., or very near 30 per cent. of the section of the narrow gauge, and as the cost of earthwork is proportional to the sections of the embankments, the slopes being the same, is it not fair to say that the difference of earthwork will be 30 per cent. of the cost of narrow gauge?

CLEARING AND GRUBBING.

I claim also that the difference between the cost of clearing and grubbing for the two roads is in the proportion of 62 to 57, as it is customary to clear 15 ft. each side outside of the slope stake. The difference between 62 and 57 is 5, which is more than $8\frac{1}{2}$ per cent. of the cost of narrow gauge.

DRAIN BOXES.

The length of the drain boxes will be reduced in the proportion of 32 to 27, or very near 19 per cent. of the cost of narrow-gauge drain boxes.

BRIDGES.

As for bridges, it may be that some of those built on wide-gauge roads and braced on a wrong plan, gave way on account of deficient lateral bracing, but the generality of those destroyed have been burnt or broken down by rupture of the chords, the lateral bracing having nothing to do with it; and I claim that the lateral bracing in the generality of the wide-gauge bridges, 16 ft. wide, answer the purpose, and that the bridges for narrow-gauge roads can be made 12 ft. wide instead of 16 ft., with a lateral bracing sufficiently strong, the light stock running on a narrow-gauge road having considerably less effect to put the bridge out of line than the heavy stock running on a wide-gauge road. Consequently the economy for bridges and culverts will be found to be 33 per cent. of the cost of bridges on narrow-gauge roads. In using cars 8 ft. or even 8 ft. 6 in. wide, there would be room enough each side to allow a man to stand without being hurt, and that is all that is needed.

LOOSE AND SOLID ROCK AND HAULING.

There will be also an economy in loose rocks, solid rocks, and hauling. In making the cuts 12 ft. wide instead of 18 ft., as they are on wide gauge, it can be seen that the difference between two cuts, 5.4 ft. high, and of very near the same section as the embankments above spoken of, will be 32.4 sq. ft., or about 30 per cent. of cost of narrow gauge.

Recapitulating, I have proved that there is in narrow-gauge roads an economy of:

Earthwork, 30 per cent. of cost of narrow gauge, or 22 per cent. of cost of wide gauge.

Clearing and grubbing, $8\frac{1}{2}$ per cent. of cost of narrow gauge, and 8 per cent. of cost of wide gauge.

Drain boxes, 19 per cent. of cost of narrow gauge, and 16 per cent. of cost of wide gauge.

Bridges and culverts, 33 per cent. of cost of narrow gauge, and 25 per cent. of cost of wide gauge.

Loose and solid rock and hauling, 30 per cent. of cost of narrow gauge and 23 per cent. of cost of wide gauge.

Let us see now what economy per mile the Texas Pacific could insure by building the road for a narrow gauge, with embankments 9 ft. wide at top, and excavations 12 ft. wide at bottom.

The cost per mile between Camp's Ferry and Tyler, on the Southern Pacific, is

Clearing and grubbing	$366 00
Earthwork	7,766 15
Loose rocks	1,070 25
Hauling	2,336 20
Culverts and bridges	4,968 17

The economy would be

Clearing and grubbing	$29 28
Earthwork	1,708 55
Loose rocks	246 15
Hauling	537 33
Culverts and bridges	1,242 04
Total per mile	$3,763 35

And as it is calculated that the Texas Pacific will be at least 2,000 miles long, the economy for the whole length of the road would be $7,526,700 (seven millions five hundred and twenty six thousand and seven hundred dollars).

Now if the question is asked why we leave less side space on a narrow-gauge road than a wide-gauge one, we answer that it is because we think that the wide-gauge roads have got too much of it; but even in making the embankments 10 ft. wide, the cuts 14 ft. wide and the bridges and culverts 14 ft. wide, to which dimensions Mr. S. does not object, I am going to prove that the economy would be yet very great in comparison with embankments 14 ft. wide at top, cuts 18 ft. wide, and bridges 16 ft. wide. In supposing the embankments 6 ft. high, as before, the section of the wide-gauge road-bed will be, as before, 138 sq. ft., and that of the narrow gauge, 114 sq. ft. The difference between the two being 24 sq. ft., or 16 per cent. of the section or cost of wide-gauge embankment.

The difference between the clearing and grubbing on the two roads will be $62-58=4$, or $6\frac{1}{2}$ per cent. of the cost of grubbing on wide gauge. The difference for bridges and culverts will be $12\frac{1}{2}$ per cent. of their cost on the wide gauge. The economy for loose rocks, solid rock, and hauling, will be 16 per cent. of the cost on wide gauge.

Consequently, the economy would be per mile

Clearing and grubbing	$23 79
Earthwork	1,242 58
Loose rocks	171 24
Hauling	373 79
Culverts and bridges	621 02
Total per mile	$2,432 42

or $4,864,840 for the 2,000 miles of the road.

This is the saving that could be effected on the road-bed of the Texas Pacific, by building the banks 10 ft. wide, the excavations 14 ft. wide, and also the bridges 14 ft. wide ; and I appeal to all engineers who will, like me, examine the question honestly, to decide if it is not so.

The saving of $4,864,840 is a very great one, and so far from weakening our side of the question, it is, on the contrary, a very strong argument in favor of the narrow gauge.

Mr. S., in his review, has not spoken of the economy in clearing and grubbing loose and solid rocks and hauling. We have not made the same omission.

We therefore consider that we have carried our first point, the economy in construction of road-bed, which is, if the banks are 9 ft. wide and the cuts 12 ft., equal to 23 per cent. of the cost of wide-gauge roads; and, in the second case, if the banks are 10 ft. wide, cuts 14 ft. wide, and bridges 14 ft. wide, is equal to 15 per cent of the cost of wide-gauge roads. According to Mr. S., this would be sufficient to decide in favor of the narrow gauge ; but we will go farther. We expect to prove that on the other points we are also right.

By a process of arguing similar to the one he used for denying the importance of economy in the road-bed, Mr. S. tries to show that the economy claimed by Gen. Buell for cost of superstructure is equally imaginary. He says, on page 9 of his pamphlet: "The requisite weight of iron rails is generally supposed to be governed by the weight resting on each driver of the engine, and as this weight creates the adhesion, and therefore governs the power, it follows that with the same weight of train, it must be equal on both gauges." This would be true if, on narrow-gauge roads, to haul a certain amount of live load they were using cars having a proportion of dead weight to the live weight or capacity as great as that of the cars used on wide-gauge roads; but this is far from being the case, as on narrow gauge they can haul the same amount of live load as on a wide-gauge road with a lighter train, with less dead weight of cars, although using a greater number of them, and consequently are able to run them on a lighter rail, as we will prove hereafter.

The rail used on the Denver and Rio Grande, and most of the 3-ft. gauge roads, is a 30-lbs. rail. Gen. Buell recommended a 36 lbs. rail for a 3 ft. 6 in. gauge. We will show that the economy of superstructure amounts to something more than the reduced length of the ties. If the rails are lighter than the fish plates, spikes and bolts will also be lighter, and the ballast will be used in smaller quantity.

We give here the comparative estimate of the superstructure of two roads, one with a 4 ft. 8½ in. gauge, the other with a 3 ft. 6 in. gauge. In the former we will suppose the rail to weigh 55 lbs., and in the latter 35 lbs. per yard.

Cost of superstructure for 4′ 8½″ gauge, 55 lbs. rail.

87 tons of rails at $70 per ton	$6,090
400 rail splices at $1	400
5,500 lbs. of spikes at 5c	275
2,640 cross ties at 80 cents	2,112
2,000 C yds. of gravel ballast at 50 cts	1,000
Laying one mile of track	500
Total per mile	$10,377

Cost of superstructure of 3′ 6″ gauge, 35 lbs. rail.

55 tons of rails at $75 a ton	$4,125 00
528 tons of rail splices at 60 cents	316 80
3,520 lbs. spikes at 6 cts	211 20
3,520 cross ties 5′×5″×6″ at 40 cents	1,408 00
1,200 C. yds. gravel ballast at 50 cents	600 00
Laying one mile of track	350 00
Total per mile	$7,011 00

Mr. Seymour, who thinks that the economy for the superstructure is only in the ties, will observe that we put more ties on the narrow gauge than on the wide one, and that the economy of superstructure is $3,366 per mile, or very near 45 per cent. of the cost of superstructure of narrow gauge, and 32 per cent. of the cost of superstructure of wide gauge. From this estimate it will be seen that the Texas Pacific Company, in building a 3 ft. 6 in. gauge road, might economize 2,000 times $3,366, or $6,732,000 in the superstructure. This, added to the economy on the road-bed in building the banks 9 ft., would make a total economy of $14,258,700, and in case the banks should be built 10 ft. wide, an economy of $11,596,840, and this, on ordinary railroad ground. It is principally in countries like New Mexico, Arizona, and California, which the line will have to cross, that the Company might make an immense saving by adopting the narrow gauge.

The adoption of a narrow gauge allows sharper curves for the line, and saves, furthermore, much of the heavy expense of tunnelling.

Herewith we give some important reports bearing directly upon the points at issue.

Gen. Wm. J. Palmer,

Pres't D. & R. G. R. R. Co.

Dear Sir—I have the honor to submit the following comparative estimate of cost for a broad and narrow gauge road from Golden City to Blackhawk, distance 20 miles :

BROAD GAUGE 4 ft. 8 ½ in		NARROW GAUGE 3 ft.		Difference in favor of narrow gauge.
	Per mile.		Per mile.	Per mile.
Golden City to mouth of North Fork of Clear Creek, 13 miles, max. grade, 125 ft., max. curve, 12°; from North Fork to Blackhawk 7 miles, max. grade 155 ft., max. curve 12°.		Golden City to Blackhawk, distance 20 miles, maximum grade 175 ft., maximum curvation 26°.		
Graduation, masonry, bridging and ballasting	$46,425 00	Graduation, masonry, bridging and ballasting	$7,200 00	$39,225 00
Superstructure, track, etc	13,610 00	Superstructure, track, etc	8,765 00	4,845 00
Depot buildings, repair shop, tanks,	1,220 00	Depot buildings, repair shop, tanks	1,000 00	220 00
Engineering superintendence and contingencies	4,500 00	Engineering, superintendence and contingencies	1,500 00	3,000 00
Total cost per mile	$65,755 00	Total cost per mile	$18,465 00	$47,290 00

Cost of broad gauge per mile	$65,755
" narrow " "	18,465
Difference in cost per mile	$47,290
Cost of broad gauge for 20 miles	$1,315,100
" narrow " " 20 miles	369,300
Difference in cost for 20 miles	$945,800

The Denver and Rio Grande Railway use

For width of road-bed in cuts	12 ft.
" " " in banks	10 ft.
Sharpest curve	6°
Maximum grade (for nearly 30 miles)	75 ft. per mile.
Length of ties	6½ ft.
Weight of iron	30 lbs. per yd.
Slope of earth cuttings	1 to 1.
" banks	1½ to 1.
" solid rock cuttings	¼ to 1.

These estimates are made from careful surveys, the most of the lines being actual locations ; the curved lines having been run at all the most difficult points.

Having no reliable data from which to estimate the cost of rolling stock, etc., particularly the motive power for operating on grades of 150 to 175 ft. per mile with the maximum curvature of 26 deg. I have not given an estimate for equipment.

Estimated weight for iron rails as follows :

For broad gauge	65 lbs. per yard.
" narrow "	40 " "

There would appear to be a discrepancy in the engineering and contingency estimate (by comparison), but is accounted for by the difference in length of time to construct; there being unavoidably 3 tunnels on the broad gauge (if only 12-deg. curves are used), which would keep up an organization for engineering and superintendence 2 years instead of 6 or 8 months, in which the narrow gauge can be completed.

The extension of line from Blackhawk to Central City can be made at the average cost for narrow gauge given, distance about 7 miles; but I think it hardly possible to build for broad gauge with 12 deg. curves. Very respectfully,

(Signed) J. P. Mersereau,

Chief Eng'r.

UNION PACIFIC R. R. CO.
GENERAL SUPERINTENDENT'S OFFICE,
OMAHA, NEBRASKA, *Nov.* 9, 1871.

MY DEAR SIR,—I inclose you the Directory with blanks filled up as requested.

An approximate location has been made during the last two months from Pine Bluff to Nevada, Cal., and the line has been definitely located from Golden City to the forks of Clear Creek, 13½ miles. Of this distance 5 miles have been graded since the 1st of September, on which occurs the heaviest work through the cañon. On this 13½ miles the creek falls 1,700 ft. The cost of grading a road-bed through the cañon for a 4 ft. 8½ in. track was estimated to be $90,000 *per mile.* The *actual cost* of grading a road-bed for a 3 *ft. track* has not exceeded $20,000 *per mile.*

It is expected that the road will be completed from Pine Bluffs to Nevada by the 1st of September next, and a branch 22 miles long from the forks of the creek to Georgetown, by Jan. 1st, 1873. A third rail will be laid on the ties between Denver and Golden City, 15 miles, making the entire length of Colorado Central R. R. and branches—192 miles narrow gauge and 15 miles of 4 ft. 8½ in. gauge.

Respectfully yours,
(Signed) T. E. SICKELS,*
Ch'f Eng'r C. C. R. R.

To Dr. R. H. LAMBORN,
Vice Pres't D. & R. G. R. R.

Considering the saving announced by Mr. T. E. Sickels as somewhat extraordinary, I wrote to that gentleman to ask him some explanations, and obtained the following reply:

UNION PACIFIC R. R. CO.
GENERAL SUPERINTENDENT'S OFFICE,
OMAHA, NEBRASKA, *Nov.* 28, 1871.

CH. J. QUETIL, Esq.,
Ass't Eng'r Texas Pacific R.R., N. Y.

DEAR SIR,—I have received your letter of 20th instant. The large difference in the cost of grading for a broad-gauge and for a narrow-gauge railroad through Clear Creek Cañon, Colorado, results from the fact that the location of the two lines occupy different ground.

On the broad-gauge location the minimum radius of curvature adopted was 955 ft., and on the narrow gauge it is 220 ft. The cañon is about 3,000 ft. deep and has precipitous sides. Its course is so tortuous that the broad-gauge location would have required in construction numerous tunnels and bridges across the stream, with high embankments and deep open rock cuttings. The adoption of a narrow gauge admitted of an alignment conforming approximately to the windings of the cañon, and enabled us to obtain a graded road-bed for less than ¼ of the estimated cost of a broad-gauge road-bed, with the additional advantage that increase of distance secured more favorable grades.

Yours truly,
T. E. SICKELS,
Ch'f Eng'r C. C. R. R.

I leave it to the stockholders of the Texas Pacific to decide what an immense saving on the cost of the road might be made in the tortuous hills of Arizona and California, by adopting a narrow gauge.

Mr. S. in his review shows his complete ignorance of the dimensions of cars used on narrow-gauge. He assumes that the cars of a narrow-gauge road will be only 1 ft. 2½ in. smaller in width than those of the wide-gauge and allows for no reduction in length.

He says: "The saving in the cost of each car will be only the value of a longitudinal section of 1 ft. 2½ in. taken from the centre of the car, embracing only the top, bottom, and two ends of the body, and the truck frames and axles below, and perhaps a still further trifling deduction on account of the value of materials, and labor claimed to be saved in the construction of cars of the proposed diminutive width; but I claim that the additional number of cars required to transport the same amount of tonnage, or number of passengers, will make the cost quite as much if not more, for the narrow than for the wider gauge."

So that Mr. S., in writing that new sentence, thinks or tries to make people think that to make a narrow-gauge car, it is only necessary to make it of the same length and 1 ft. 2½ in. narrower than those used on wide-gauge roads. By assuming this, he not only proves that he has not read the report of Gen. Buell, who gives the dimensions of narrow-gauge cars, but also that he lacks the first knowledge necessary to discuss the subject, viz.:

* Gen'l Sup't Union Pacific R. R.

the knowledge of dimensions of cars used on narrow gauge. He thinks (p. 13) that we ought to have gone to the New York Central and Erie Railway depots to learn something about dimensions and capacities of cars. We will give him the advice to visit at Wilmington, Delaware, the large car shops of Jackson & Sharp, and those of Harlan & Hollingworth, and also those of Billmeyer & Small, at York, Pa. Those establishments are now making new cars for about 20 narrow-gauge railroads, and Mr. S. will be able to learn something about their dimensions.

If he wants to see the cars running and how they stand the gales of Colorado, and also what amount of live load they are able to carry, he can complete his travel by visiting the Denver and Rio Grande Railroad.

He will learn that Jackson & Sharp are building for narrow-gauge passenger cars 35 ft. long, 7 ft. wide, and 16 ft. 6 in. high, to carry 36 passengers, instead of cars 48 ft. long in body, and 54 ft. long over platform, 9 ft. 6 in. wide, 7 ft. 10 in. high at sides, and 10 ft. 3 in. high at dome, and built for 60 passengers, and on the 4 ft. 8½ in. gauge roads.

Also that Billmeyer & Small are building platforms (4-wheeled) 12 ft. 6 in. long and 6 ft. wide, and some others 16 ft. 6 in. long.

Also 8-wheeled platform cars, 23 ft. 6 in. long and 6 ft. wide, instead of 32 ft. long and 9 ft. wide, as on the wide-gauge roads.

Also 4-wheeled box cars 10, 12, or 14 ft. long, and 6 ft. wide.

Also 8-wheeled box cars, 22 ft. long and 6 ft. 6 in. wide, instead of 29 ft. long and 9 ft. wide, as they are built for 4 ft. 8½ in. gauge roads. He will be able to satisfy himself that 8-wheel box cars, same length as that shown in Gen. Buell's report, and only 1 ft. narrower, and with 2 trucks of 4 wheels each, and of same form as the trucks indicated in Gen. Buell's report, are built at Billmeyer & Small's, York, Pa., for the Denver and Rio Grande Railroad, and that I have in Gen. Buell's office the photograph of one of those cars bearing "No. 2,001, D. & R. G. R. W.," and that consequently his assertion (p. 13 of his pamphlet) that the box car indicated in Gen. Buell's report is "only in theory and upon paper," is erroneous, and shows still more his ignorance of the facts, as the same car which is built 6 ft. 6 in. wide could certainly be built 1 ft. wider and run under the same conditions.

We will complete our informations to Mr. S. by adding some statistics of the weight and capacity of these cars.

Harlan & Hollingworth are building for 3 ft. gauge roads box cars 14 ft. long, 6 ft. wide, 7 ft. 6 in. high, weighing empty 4,500 lbs., and with a capacity of 8,000 lbs. Those cars are running on the Denver & Rio Grande R.R. The 4 wheeled box cars with box 10 ft. long, frame 12½ ft. long and 6 ft. wide, built by Billmeyer & Small, weigh 4,500 lbs. empty and have a capacity of 9,500 lbs.

Their 4 wheeled flat cars, whose dimensions I gave before, weigh 3,500 lbs. empty and have a capacity of 10,500 lbs. They are also running on the Denver & Rio Grande R.R. The 8 wheeled platforms weigh 6,250 lbs. empty and have a capacity of 20,000 lbs. The 8 wheeled box cars weigh empty 8,800 lbs. and have a capacity of 16,000 lbs.

The passenger cars built by Jackson & Sharp for 36 passengers weigh 15,000 lbs., the dead weight per passenger being 416 lbs.

Let us now compare the proportion of dead weight to live weight in the narrow gauge cars with this of the 4 ft. 8½ in. gauge cars.

FOR NARROW GAUGE:

4 wheeled flat cars......	$\frac{3{,}500}{10{,}500}$	proportion 33.3 per cent.
8 wheeled do.	$\frac{6{,}250}{20{,}000}$	" 31.2 "
4 wheeled box cars.....	$\frac{4{,}500}{9{,}500}$	" 47.3 "
8 " " "		..55 "

8 wheeled passenger cars for 36 passengers, dead weight per passenger 416 lbs.

FOR 4′ 8½″ GAUGE.

8 wheeled flat cars 32 ft. × 9 ft.	$\frac{16{,}500}{22{,}400}$	proport'n 73.6 per cent.
8 wheeled box cars 29 ft. × 9 ft.	$\frac{18{,}000}{22{,}400}$	proport'n 80.4 per cent.
8 wheeled passenger cars for 60 passengers 48 ft. long by 9 ft. 6 in wide........	$\frac{39{,}000}{7{,}200}$	Dead weight per passenger equal to 650 lbs.

Consequently, there is in favor of the narrow gauge an economy of dead weight of:

For flat cars........	42.4 per cent.
For box cars....................	33.1 and 25.4 per cent.
For passenge cars	234 lbs. per passenger.

Page 14 of his review Mr. S. says: "And

will he or any other advocates of this extreme narrow gauge theory, undertake to demonstrate why a platform 10 ft. square, and capable of upholding a given maximum weight, should necessarily be of more than twice the weight and strength of one 10 ft. long and 5 ft. wide, and capable of sustaining just one half of the same maximum weight."

In asking such a question, Mr. S. shows, I repeat it again, his ignorance of the way the narrow-gauge cars are built.

He assumes that to build a narrow-gauge car platform it is only necessary to cut in two, lengthwise, the platform of a broad-gauge car, and to move only one of the inside sills to make of it the outside sill of the new platform, reducing the width only.

Of course, if such a platform was cut in two equal parts in the line of its longitudinal axis, each of the parts ought not to weigh more than the half of the weight of the first platform; but this misrepresents the true proportions of narrow-gauge cars, and conceals the fact that these cars can carry the same load with less weight of car than the broad gauges.

To enable Mr. S. to understand this, we will offer some remarks on strength of materials.

If a beam or sill of a given length, and supported at each end, is able to carry a certain weight, when I cut the beam or sill in two parts, equal in length, and support one of those part, at each end, this half beam or sill, with half the material and weight of the first one, will support double the weight that the first one could carry. In other terms, if a beam 12 ft. long, 2 in. broad, and 4 in. deep, can, when supported at each end, carry 1,000 lbs., another beam 6 ft. long, same width and same depth as the preceding, will be able when supported at each end to carry 2,000 lbs.

Now, what is a platform? It is a flooring supported by a certain number of longitudinal and transverse beams or sills. What support at each end, or very near it, those longitudinal beams or sills? The trucks of the car. Consequently, if the platform 10 sq. ft., spoken of by Mr. S., has 4 longitudinal sills, and is able to carry 4,000 lbs., each of those sills will be able to carry 1,000 lbs. If we cut them across in two equal parts, each of those new sills 5 ft. long will be able to carry 2,000 lbs. and we may have a new platform 5 ft. long and 10 ft. wide which will weigh half as much as the first one and will be able to carry double the weight. This is the whole secret of the economy of dead weight that the narrow-gauge car builders effect in reducing the length of the sills of the cars and not their width, without reducing their length, as Mr. S. would lead his readers to believe. On what narrow-gauge road or which narrow-gauge car shop has Mr. S. seen builders reducing the width of the cars used on wide-gauge roads without reducing at the same time their length? Does he think that car builders would any way reduce the width of the cars without reducing also their length? They know better. They know that it is principally in reducing the length of the cars that the economy of dead weight is effected. If in the above mentioned platform, 5 ft. long by 10 ft. wide, we diminish by one half the width of each of the four sills, we shall have a platform weighing a little more than one-fourth of the first platform and able to carry the same weight. This diminished weight of the platform will allow us to run it on smaller wheels, and consequently to lower its centre of gravity. The centre of gravity being lowered, it follows as a natural consequence, that the gauge might be reduced, and the platform run with the same stability, as one on a 4 ft. 8½ in. gauge running on larger wheels. So far, in building for narrow-gauge roads, the car builders have only succeeded in making a reduction of weight of the half or the two-thirds of the weight of the 4 ft. 8½ in. gauge cars for carrying the same live load; but this result is satisfactory enough. The broad gauge advocates will now say that they could build for their roads cars just as small as those used on narrow gauge and with the same proportion of dead weight to live weight. We admit that they could reduce considerably the dimensions of their cars, and diminish the proportion of dead weight to live weight; but we hold that, retaining the same gauge, this proportion can never be as small as on narrow-gauge roads. We maintain that if they reduce the dimensions of their cars without reducing in proportion the diameter of their wheels, and this in order not to break their draw-head, they will have each of their cars weighing about 800 or 1,000 lbs. more than the narrow gauge cars running on smaller wheels and of same capacity. If they reduce the diameter of the wheels and economize to 100 or 125 lbs. per each wheel, they will experience a difficulty just as great as that occasioned by the breaking of gauge. They will break the drawhead of their cars. Some of their cars running on 33 in. wheels will have their drawhead at 33 in. above the rails; the others running on 24 in. wheels will have their drawhead at 24 in. above the rails. Difference between the drawheads 9 in. The cars could only be coupled by heavy bars of flat iron like those used for coupling the tender of the locomotive to the train. Any upset ordinary link of round iron would not do. It would stretch or break. The use of such coupling bars would be unhandy and expensive.

We also maintain that, diminishing or not the diameter of their wheels, they will find another difficulty: that of the liability of the new small cars to be crushed by the old ones, which are heavier and have more momentum.

These two difficulties: the breaking of the drawhead and the liability of the light cars to be crushed by the heavier ones, are the two principal reasons which prevent managers of broad-gauge roads from building a lighter stock. If it is not so, we will ask them why they do not do it, when they might make such a great saving of money by it.

There is also a reason why new companies with a 4 ft. 8½ in. gauge do not build a lighter stock. They fear to let light cars go on others' roads to be mixed up with heavy cars, for fear they would be crushed; the heavy cars would override them in a sudden halt or collision.

The difficulties in the way of using lighter rolling stock on wide-gauge roads, as mentioned above, are so great that they have been considered by several newly organized companies as worse than breaking the gauge, and these companies have preferred to avail themselves entirely of the great saving which exists in having cars of such small weight and such great capacity as those running on narrow-gauge roads; and, feeling that they could not with safety let their light cars go on broad-gauge roads, or allow the heavy broad-gauge cars to come on their roads, they judiciously adopted a narrow gauge, and, building all their stock uniform for that gauge, they averted the difficulties above mentioned. By running their light cars on smaller wheels, 24 in. instead of 33, they saw that the centre of gravity of those light cars was lower than that of the broad-gauge cars, and that consequently they could reduce the gauge in proportion and run their cars with the same angle of stability as the broad-gauge cars.

The reduction of gauge, I maintain, is a natural consequence of the diminution of the dimensions of cars and of their wheels. The lowering of the centre of gravity allows the reduction of the gauge and gives an economy per car in the reduction of weight of axles and break beam, which I estimate at 80 lbs.

There may be on the New Jersey Central one or two cars of reduced dimensions, but is there in all the United States a railroad with a 4 ft. 8½ in. gauge with all its stock of cars as light in regard to their capacity as those run on the Denver and Rio Grande? I think not. Why do not any of those newly built wide-gauge roads run a light stock on 24-in. wheels? Is it not clearly for the reasons given above? So that the broad-gauge companies are compelled to keep their costly stock built under such unfavorable conditions as regards the proportion of dead weight to live weight. The best proof of this is, they do not alter it, and that even in renewing their stock there is no tendency to reform in that respect, as far as I know.

New companies who wish to economize as much as possible in building their road and stock, and fuel, prefer to adopt the narrow gauge. By so doing, they avail themselves of all the economy possible in dead weight.

The only inconvenience they experience is the breaking of bulk, but they know that the immense saving they effect in adopting the narrow gauge and corresponding stock, compensates a hundred times the inconvenience and expense of changing cars and breaking bulk. I believe, like my opponent, Mr. S., that the great damage and inconvenience growing out of an interchange of cars upon thousands of miles of connecting, and in many instances hostile or competing lines, overbalance any good or real saving to the stockholders that may result from it.

I use here the same expressions as Mr. Seymour, in his pamphlet (page 32), and it is one of the very few points on which I agree with him.

One of the great objections made against narrow gauge is the supposed want of room and comfort in the passenger cars. This objection has no foundation whatever. The passenger cars running on the Denver & Rio Grande are the best answer to it. Those cars are built with three seats across on a line instead of four. On one side of the car, for half of the car, are the double seats and on the other side the single seats. In the other half of the cars the single seats are on the left and the double seats on the right. I do not see why for each of these seats there should not be just as much room given to each passenger as there is in the broad-gauge cars.

I will now show Mr. S. why the rails on narrow-gauge roads may be lighter than those generally used on wide-gauge roads.

If with a box car weighing empty 4,500 lbs. I carry a load of 8,000 lbs., is it not true that to carry a load of 80,000 lbs. it it will take 10 of those narrow-gauge cars, weighing altogether 45,000 lbs.?

Also, if a wide-gauge car (4 ft. 8½ in. gauge) weighing empty 18,000 lbs., has a capacity of only 22,400 lbs., is it not true that to carry 80,000 lbs. it will take 3 and $\frac{57}{100}$ cars, weighing altogether 64,000 lbs.

Can I not consequently carry with the narrow-gauge cars a load of 80,000 lbs. with 19,000 lbs. less dead weight than if using the 4 ft. 8½ in. gauge cars. Let us suppose now a train of 60 cars on the narrow-gauge road. Those 60 box cars will haul 480,000 lbs. of live weight and will weigh 270,000 lbs., and the whole train will weigh 750,000 lbs., or 334.84 tons.

To haul the same load on a 4 ft. 8½ in gauge with the cars now in use on such roads, it would take 21 and $\frac{3}{7}$ cars, weighing altogether 385,704 lbs., so that the whole weight of the train would be 865,704 lbs. or 385.65 tons—a difference of 115,704 lbs. of weight, or 51.65 tons, in favor of the train running on narrow gauge and composed of 60 loaded cars.

Supposing now the resistance to be 10 lbs. per ton at a speed of 12 miles per hour on straight and level line, and the two trains running at that speed. Supposing also that the freight engines used on each gauge have six wheels each; is it not evident that the weight on each of the drivers of the narrow-gauge engine will be less than the weight on the drivers of the wide-gauge engine, and that consequently the rails on the narrow-gauge road can be lighter. The adhesion on rails of the narrow gauge will be 3,348.40 lbs., or 558 lbs. for each driver.

Supposing now the adhesion to be in dry weather 600 ℔s. per ton of load on drivers, the load on each driver will have to be $\frac{93}{100}$ ton, or 5.58 tons for the six drivers. Such an engine, if it comes from Baldwin Works, Philadelphia, would weigh 15,000 ℔s., having 12,499 ℔s., or 5.58 tons on the drivers. But that engine must overcome the resistance caused by the friction of her different parts, a resistance equal to $6.69 \times 15 = 100.35 + 334.84 = 435.19$ ℔s., the resistance of friction of the engine being generally considered equal to 15 ℔s. per ton of weight of the engines, to which must be added 1 ℔. for each ton of the load drawn by it. This resistance of the locomotive itself will require a new load on the driving wheels equal to

$$\frac{435 + 2240}{600} \text{ or } 1624 \text{ lbs.}$$

The total weight on each driver would be then $\frac{93}{100} + \frac{12}{100}$ of a ton or 1.05 ton. Such an engine could run on level and in straight line on a rail weighing 12.6 ℔s. per yard.

Let us make now the same calculation for the engine running on the 4 ft. 8½ in. gauge. The total weight of the train being 386.65 tons, the total resistance of the train will be 3,866.5 ℔s., or 644.4 for each driver. To cause this adhesion there will be necessitated 1.07 ton of load on each driver, or 6.42 tons on the six drivers. Supposing that the load on the drivers in the 4 ft. 8½ in. gauge engine is in the same proportion to the total weight of the engine as in the narrow-gauge engine; such an engine would weigh 17,257 lbs., and would have a resistance of friction of its parts equal to $15 \times \frac{17257}{2240} + 386{,}65 =$ 502 lbs.

This additional resistance will necessitate an additional adhesion, which must be obtained by an additional weight of 1,874 lbs. on the drivers, or 2,249 lbs. to the engine. So that the engine ought to weigh 190,506 lbs. and throw 16,255 lbs. on the six drivers, or 2,709 lbs. = 1.21 ton on each driver.

By using the same formula, $W = L \times 12$, that we used before, to find the weight of rail per yard corresponding to the narrow-gauge engine (in which W represents the weight of rail per yard, L the load in tons on each driver), we find that such an engine on level, would require a rail of $14\frac{1}{2}$ lbs. per yard.

This gives an economy of 2 lbs. per yard in favor of the narrow-gauge rail, the economy being small in this case, because the comparison has been made between two light trains running on a level, and in straight line.

We have assumed that the engine used on the 4 ft. $8\frac{1}{2}$ in. gauge road would throw, like that of the narrow gauge, 83 per cent. of its weight on the drivers, which is not the case, as an ordinary 6-wheel freight engine on a 4 ft. $8\frac{1}{2}$ in. gauge road, 18-in. cylinder, and 24-in. stroke weighs 66,750 lbs. and throws only 43,750 lbs. on the drivers, or about $65\frac{1}{2}$ per cent. of its weight, instead of 83 per cent., and consequently the 4 ft. $8\frac{1}{2}$ in. gauge engines, being heavier in proportion than the narrow-gauge engines, will have a greater resistance of friction in their parts proportionally, and will require proportionally more weight on their drivers, and consequently a heavier rail.

I will now show that the heavier the grades the greater will be the difference between the weight per yard of the rails on the two roads.

Let us suppose that on both roads the engines have to go up gradients of 48 ft. per mile, and to draw the same live load at the same speed of 12 miles an hour. Of course, both of them must be more powerful, heavier, and with more load on the drivers than for a level line.

It has been found by experience that an engine running at a rate of 12 miles per hour on level and in straight line with a resistance of 10 or $10\frac{1}{4}$ lbs. per ton, when it has to run at the same speed up a grade of 48 ft. per mile, can only draw at that speed the third part of the load she could draw on a level; or, in other terms, to draw on that grade the same load that it could draw on a level and at the same speed, she ought to be three times as powerful and have three times as much weight on the drivers. The engine on the narrow gauge must therefore have 3.15 tons, and the engine on the wide gauge 3.63 tons on each driver.

The rail for the narrow gauge will have to weigh 37.8 lbs., and the rail for the wide gauge 43.56 lbs. per yard.

The difference being 5.76 lbs. per yard.

It is well to observe, at once, that the rails on a 4 ft. $8\frac{1}{2}$ in. gauge weigh generally from 55 to 60 lbs. a yard, because they draw heavier trains than one weighing 386.5 tons live load included, because the grades are generally in some parts of the roads heavier than 48 ft. a mile and also because the roads instead of being in straight line, as I supposed it in my comparison, have curves, and also are exposed to strong gales acting sometimes in front, sometimes on the bulk of the trains by their sides, all causes necessitating more powerful and heavier engines and also heavier rails. The greater this resistance the greater must be the disproportion in weight of rails between the wide and the narrow gauges.

On the other hand, the rails on a 3 ft. gauge are lighter than 37.8 lbs., generally only 30 lbs a yard, because on those roads it is not customary to haul more than 184 tons instead of 334 tons under the supposed conditions.

I have in my comparisons neglected the resistance of the curves on both gauges, and have not taken advantage of the diminution of frontage in the narrow-gauge cars in determining the resistance of the air. The resistance, 10 lbs. per ton, includes the friction of the cars, the resistance of the air front and side of train and the resistance due to concussion and imperfection of road. The resistance caused by friction of cars being estimated at 6 lbs. per ton of weight of train, the resistance of air at $\frac{1}{400}$ lb. per sq. ft. of frontage and for a velocity of 1 mile, and the resistance caused by concussion and imperfection of road at $\frac{1}{3}$ lb. for each ton of the train at a velocity of 1 mile per hour; all these resistances having been carefully and exactly determined by the experiments made by Mr. Scott Russell.

In the example above given the engine for narrow gauge throwing 18.9 tons on its six drivers and weighing 22.7 tons, would be accompanied by a tender of 1,600 gallons, weighing 13,000 lbs. when empty and 32,000 when loaded. I have for this the authority of Messrs. Baird & Co., who are building narrow-gauge engines at Philadelphia. This makes the total weight of engine and tender when empty equal to 63,848 lbs. and equal to 82,848 lbs. when the tender is loaded.

The engine for 4 ft. 8½ in. gauge, which throws 21.8 tons on its drivers and would weigh 26.2 tons, would be accompanied by a tender weighing 34,000 lbs. when loaded, and of a capacity of 1,800 gallons, so that the total weight of the engine and tender would be 92,688 lbs., making a difference of 9,840 lbs. of dead weight in favor of the narrow gauge.

It is well to remark here that although the Baldwin engines are built in very good conditions, throwing 83 per cent. of their weight on the drivers, still they require, to do the same work, a heavier rail than would a Fairlie engine, and I will seize this opportunity to call attention to the advantages, in my opinion, of that new system of locomotives, the Fairlie engine. It is, in my opinion, the one which gives the greatest tractive power and adhesion with the minimum dead weight of engine.

There have been no locomotives of another system built yet, that I know of, weighing only 60 tons, tank included, and having a tractive power of 35,550 lbs., or 26 per cent. of the dead weight. The Baldwin locomotives, weighing 41,000 lbs. with their tank empty, have only a tractive power of 7,300 lbs., or 18 per cent. of the dead weight of engine and tender.

I have also the proofs that the Fairlie engines perform well and are more economical than any other kind of engines as regards consumption of fuel. They have the enormous advantage of throwing their whole weight on the drivers; on a 36 lbs. rail put on a 3 ft. or 3 ft. 6 in. gauge road, you can, with a Fairlie freight engine of 12 wheels weighing 36 tons, have the same tractive power that would be given by 2 ordinary freight engines of 6 wheels each, weighing each 27½ tons and throwing 43,750 lbs on the drivers. The economy of dead weight being, therefore, 42,456 lbs. in favor of the Fairlie engine, which could draw on a 36 lbs. rail on level, the same load that ordinary engines could not draw with safety without running on a 39 lbs. rail, the distance between the centres of the ties being in each case 2 ft.

Consequently, in the above comparison I made, if a Fairlie engine was employed on the narrow gauge and ordinary engines on the 4 ft. 8½ in. gauge, the weight of the rails on the narrow gauge might be only 34.8 lbs. per yard instead of 37.8 lbs., as we found before, while those on the wide gauge ought to weigh 43.56 lbs. per yard, giving a difference of 8.76 lbs. per yard in favor of the narrow gauge when a Fairlie engine is used.

In examining the proportion of weight on the drivers to the whole weight of the engine in those cited by Mr. S. (p. 29 of his pamphlet). I see that an engine of a total weight of 66,050 lbs. has only 40,050 lbs. or 60 per cent. of its weight on the drivers; that another on the Lehigh Valley Railroad, a 10-wheeled engine of a weight of 78,000 lbs. has only 63,000 lbs. or 80 per cent. of its weight on the drivers, and I remark that the weight of the tenders has not been given with those of the engines. The one of the New York & Erie, weighing 66,050 lbs., must be accompanied by a tank weighing at least 42,000 lbs., so that it throws on the drivers only 37 per cent. of the total weight of engine and tender. The 10-wheeled engines of the Lehigh Valley Railroad, weighing 78,000 lbs., must have tenders weighing at least 36,000 lbs., so that they throw on the drivers only 55 per cent. of the total weight. The Consolidation engines, weighing 86,000 lbs., must have tenders weighing at least 36,000 lbs., so that they throw on the drivers 62 per cent. only of the total weight. None of them, like the Fairlie engine, throws the total weight of engine and tank on the drivers, and I will call the attention of Mr. S. to the fact that the broad-gauge engine of the New York & Erie road, is, in that respect, in the worst condition.

I cannot understand why the Fairlie engines are not getting popular in this country. The engines built by Messrs. Baird & Co. throw on their drivers only 59½ per cent. of the total weight of the engine and tender. It is considerably more than the broad-gauge engines can do, but it is very far yet from what the Fairlie engine does. These latter are like all new things; however good they may be, they meet at first only incredulity and opposition.

Mr. William Mason, of Taunton, Massachusetts, has built one weighing, in working order, with its tanks and coal bunkers full, from 60 to 70 tons, and he says: "Notwithstanding the great weight, the machine runs so smoothly on the track that I am quite certain that it is not as destructive to the rails as an ordinary 8-wheeled engine. It will go around a curve of 150 ft. radius with as much ease as a 12-wheeled car, and it will haul the load of 4 ordinary 8-wheeled machines of the same-sized cylinder."

The generality of the American builders criticise them and try to create the impression that they are not economical, but we know from engineers and managers of roads where they have been at work, that not only are they economical but are more so than the generality of engines now in use. We give here a copy of a letter addressed to Mr. R. F. Fairlie by Mr. A. McDonnell, Chief-engineer of the Great Southern and Western Railroad of Ireland, who is using the Fairlie locomotive on his line :

GREAT SOUTHERN AND WESTERN RAILWAY,
LOCOMOTIVE ENGINEER'S OFFICE,

July 19th, 1870, Inchicore, Dublin.

R. F. FAIRLIE, Esq.,

DEAR SIR,—In reply to your inquiries as to the two double bogie engines built in these works on your system, one has run 5,677 miles, and the other 3,867 miles. They both worked as pilot engines, when turned out new, and afterwards as passenger engines with slow trains ; the average running speed of the trains they work is from 25 to 30 miles an hour, and the load from 4 to 9 of our large 6-wheeled carriages. The weight on the wheels is well distributed, being 10 tons on each pair of wheels of the steam bogie, and 8 tons on each pair of wheels of the trailing bogie in working order, with water enough to run from 20 to 25 miles, and coal enough for the run from Dublin to Cork (165 miles.

The engines make steam extremely well and the consumption of coal is low. The drivers consider its 3 or 3 lbs. a mile less than the average. I will, however, let you know more exactly soon, when they have worked longer as train engines.

The engines work very freely, run very steadily, and are very handy.

They have given no trouble except a little with the steam pipes, which I have altered since. They will run round curves of 100 ft. radius, and run freely round curves of 300 ft. radius, which is all I require them to do in practice.

Yours truly,

A. McDONNEL.

I will add to this that General Buell has received a letter from Mr. B. Saloff, Chairman of the Board of Management of Railroads in Russia, giving him some details about the construction of narrow-gauge roads and the performance of the Fairlie engines in Russia. Here are extracts of that letter : "These engines take a train of 61 loaded wagons, gross load 410 tons, the length of the train exclusive of engine being 896 ft., at the rate of 10 miles an hour up grades of 1 to 80 or 66 ft. a mile, and consume only 3.03 cubic ft. of wood per mile. There is room on the engine for 320 cubic ft. of wood, 198 cubic ft. of water in the tanks, and 130 cubic ft. of water in the boiler." That letter was written to General Buell by order of Count Alexis Bobrinsky, Minister of Public Works in Russia, in answer to one written to him by Gen. Buell and asking information about the narrow-gauge roads in Russia.

Mr. S., who writes (page 29 of his pamphlet) that for the performance of engines on narrow-gauge railroads, he can only refer to theoretical and assumed results, can see that we have something better to offer. We present facts with the authority of the Minister of Public Works in Russia. The Fairlie engines are working there on the Livny railway (3 ft. 6 in. gauge.) The rails weigh 45 lbs. to the yard on account of the heavy trains hauled and of the heavy grades. If the gauge was 4 ft. $8\frac{1}{2}$ in., and the rolling stock and engines similar to those used now on such gauge roads, they could not weigh less than 60 lbs. to the yard.

The original of Mr. B. Saloff's letter is in the Archives of the Texas Pacific Railroad Company. We hope that the results of the performance of the engines of Messrs. Baird & Co., Baldwin Locomotive Works, on the Denver and Rio Grande and other narrow-gauge roads, will soon be published. Now, it is evident that the Fairlie engine would perform also very well on a broad gauge; not as well as on a narrow one, however, because the narrow gauge admits of sharper curves than the broad gauge, and it is especially in the facility of turning in the sharp curves that the advantages of the Fairlie engines are found. The greater number of their driving wheels and the equal distribution of the weight on them allows also the use of a lighter rail. These engines perform economically their work with the least dead weight possible. Mr. Fairlie, however, is mistaken when he allows himself to say that a narrow-gauge road without his engine is a delusion and a snare. The absence of Mr. Fairlie's engine from a narrow-gauge road does not reduce to naught the economy of that road in building it, equipping it, and running it. Having in the preceding demonstrated that the rails on a narrow gauge must be necessarily lighter than those on a wide, gauge road, because in the narrow-gauge cars the proportion of dead weight to live weight is less. I have then shown the error of Mr. S. when he says (page 9 of his pamphlet): "If it is claimed that the same amount of tonnage can be hauled with greater economy by *multiplying the trains* and using *lighter engines*, then I maintain that the same principle can be applied upon the wider gauge with equal economy, and therefore that no greater weight of rails is required." The calculations I have made before and the facts show the fallacy of his assertion.

In my comparison of the two engines in which 48 ft. a mile was the greatest grade on the two roads, and the same regular speed of 12 miles an hour being maintained on that grade, the engine on the 4 ft. 8½ in. gauge road does not weigh more than 26 tons. It is considerably lighter than the engines usually employed for freight on the 4 ft. 8½ in. gauge roads. These engines generally weigh from 30 to 40 tons, the weight of tender not being included. With their tanks they generally weigh 45 to 56 tons. Consequently to haul with that engine weighing only 26 tons the same load that could be hauled with one weighing 35 tons, it will be necessary to multiply the trains. I made my comparison under the circumstances preferred by Mr. S., viz.: The multiplication of trains. But he can multiply them as much as he chooses, he will never, as long as he uses the same cars which are used now on the 4 ft. 8½ in. gauge roads, avoid the contingency which I have demonstrated, that for a live load of 80,000 lbs. to be hauled at a speed of 12 miles an hour, in straight line up a grade of 48 ft. per mile, the rails on a wide-gauge road will have to weigh 43.56 lbs. per yard, while on a 3 ft. gauge road the rails need weigh no more than 37.80 lbs. per yard if an ordinary engine is used, and 34.8 lbs. per yard if a Fairlie engine is used.

As we have said before, we do not pretend that the reduction of the proportion of dead weight in cars cannot be done without reducing the gauge; we know, on the contrary, that the reduction of gauge is a consequence of the reduction of the dimensions of cars, and consequently of their dead weight, but we maintain that the broad gauge companies are bound to have each of their eight-wheeled cars, weighing 800 or 1,000 lbs. more than those on the narrow gauge, and we maintain that with a stock as light as that of a narrow gauge they lose all the advantages that they claim in keeping their broad gauge, and would find themselves in the same position as if they had broken the gauge, because their light stock does not admit of running with the heavier stock of adjoining roads, or even of being mixed with heavier stock on their own roads, without risk of crushing. That, consequently, broad-gauge railroad companies, without inconvenience amounting almost to impossibility, cannot materially reduce the dimensions of their stock and make it lighter if they want their cars to run on connecting roads, and reciprocally cars of other roads to run on their own. That if they refrain from breaking the gauge for the sake of retaining their cargoes in bulk, they are compelled to keep their deficient stock and cannot bring it in as good condition as regards the proportion of dead weight to live weight as the narrow-gauge cars, without risk of broken drawheads and crushed cars.

From what I have said before, it is evident that the reduction of gauge is a natural consequence of the reduction of the dimensions of the cars, and that the gauge must be proportional to the dimensions of the cars.

The idea of running on a wide-gauge road cars as small as those of the Denver and Rio Grande Railroad, seems to me ridiculous. What would be thought if Mr. Seymour was building a road-bed as large as that of the New York and Erie, with a track of 6 ft. gauge, and was running box cars 14 ft. long, and 6 ft. wide, and flat cars 12½ ft. long, and 6 ft. wide? Would it not strike every one, that if these same cars are running on the Denver and Rio Grande on a 3 ft. gauge, laid on a road-bed considerably smaller, and built at a considerably less expense, there can be no justification for the extra expense of road-bed and of diameter and length of axles and wheels, etc., etc.? I repeat it again, the gauge must be proportional to the dimensions of the cars, and Mr. S. in putting a flat car 12½ ft. long and 6 ft. wide, and of same dimensions of timber as those of the Denver and Rio Grande, on the 6 ft. gauge of the New York and Erie, would commit as great a blunder as if he was taking the box of a sleeping coach of the New York and Erie to put it on a truck running on a 3 ft. gauge. In the first case there would be too much stability and unjustified expense of road-bed and materials, and in the second case there would not be stability enough, and nobody would risk his life in such a car. The large cars must run on a wide gauge, and the small ones on a narrow gauge. Good common sense endorses this principle. But in case there should be in the mind of Mr. S. or anybody else any doubt about this, we are going to demonstrate it.

To do it, however, we shall have to use formulas and scientific terms. I am really sorry for it, for Mr. S., who thinks that they are not necessary for the discussion of such a question, but, if he is open to conviction, I have to do it to try to convince him. Let us state first that Gen. Buell never had any idea that his report, which was addressed to the President and Executive Board of the Texas Pacific R.R. and was not intended for publicity, would be ever read by farmers, teamsters and carters. Those men (teamsters or carters) who may be very skilful and clever in their line of business, have not, generally, sufficient knowledge to understand the matter we are discussing. Gen. Buell, writing his report for the Directors of the Texas Pacific, thinks, like myself, that it would be inappropriate and ridiculous to use terms like "top heavy," instead of "centre of gravity" in discussing this matter.

Mr. S., who wrote for the public at large, teamsters and carters included, might as well have used in his review the terms "Ouhah" and "Dje" instead of right or left, and it would have been, perhaps, still more comprehensible for the teamsters and carters, and more to their taste. I have no doubt, however, that if they saw the sleeping coach of the New York & Erie running on 24 in. wheels on the Denver & Rio Grande they would think it "top heavy," and if they saw a platform of 12½ ft. running on the New York & Erie they would find it "top light."

But let us come to our demonstration. The general formula for the distance of the centre of gravity of a body from a plane is

$$P\,X = p'\,x' + p''\,x'' + p'''\,x'''$$

which gives

$$X = \frac{p'\,x' + p''\,x'' + p'''\,x''' +}{P}$$

in which P is the total weight of the body, X, the distance of the centre of gravity from the plane, p', p'', p''', the weights of the different parts composing the body, and x', x'', x''', the respective distances of the centres of gravity from the plane.

Let us now suppose the body to be a car, and for greater simplification, let us admit that the different parts forming this car can have their weight concentrated at four different points when the car is empty and five different points when loaded.

Those points being, viz.:

1*st*. The trucks including all that is below the sills of the cars, save the bunters and cross-beams resting on trucks, and such as wheels, axles, bolsters, brakes, brake beams, iron rods, etc., all the weight of which can be approximatively considered as acting at the centre of the wheels.

2*d*. The weight of the sills, flooring, crossbeams, bunters and platforms, which we will consider as acting at the centre of gravity of the sills.

3*d*. The weight of the box (roof not included), which we will suppose to act at the middle of the height of the box.

4*th*. The weight of the roof acting at the centre of gravity of the roof.

5*th*. The weight of the live load acting at the centre of gravity of the volume occupied by that load at the top of the flooring.

Let us also suppose the plane to be the horizontal plane of the top of the rails,

p^1 will represent the weight of the trucks.

p^2 the weight of the sills, crossbeams, platforms, flooring and bunters.

p^3 the weight of the box, flooring and roof excluded.

p^4 the weight of the roof.

p^5 the weight of the load.

We can see from the formula that the centre of gravity of the car when empty is situated at a distance from the rails where the total weight of the car multiplied by that distance, equals the sum of the products of the four different partial weights of the car multiplied by the respective distances of their centre of gravity from the given plane.

Now it will be found, on experimenting on the formula, that

1*st.* If without changing any of the other weights or their respective distances from the rails, we diminish one or all the weights acting above the horizontal line in which is situated the centre of gravity, we will lower the centre of gravity.

2*d.* If we diminish the distance to the rails of one or all the weights acting either above or below the horizontal line of the centre of gravity, without changing the other distances or weights, we will lower the centre of gravity.

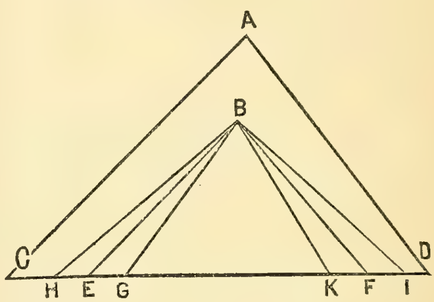
3*d.* If we diminish one or all the weights acting below the line of the centre of gravity, the other weights and distances remaining unchanged, we will raise the centre of gravity.

What are we doing, then, when we reduce the dimensions of a car as much as Jackson & Sharp and others are doing? We certainly diminish all the weights above spoken of and their respective distances from the rails, and consequently we lower the centre of gravity.

If we were reducing the weight of the trucks without diminishing the diameter of the wheels, we might perhaps keep the centre of gravity at the same height or near it, but we diminish the diameter of the wheels also, and the centre of gravity is then necessarily lowered; they run on 33 in. wheels, whatever may be the gauge, and box freight cars for example can be run on 24 in. wheels, and even 20 in. wheels, with considerably less resistance to the tractive power, than the heavy cars offer when they run on 33 in. wheels, whatever may be the gauge, and we call the attention of Mr. S. to this fact.

The formula above cited is the one which has been used by Gen. Buell and myself to calculate the position of the centre of gravity of the cars whose plans are shown in his report, and we know it to be the right one.

Having proved that the centre of gravity of one of the narrow gauge cars above cited, even if the wheels were apart enough to run on a 4 ft. 8½ in. gauge, is lower than that of the cars now in use on the wide gauge, I will prove that the gauge must be reduced in proportion, and that the dimensions to which it must be reduced to allow the narrow-gauge cars to run with the same stability, as regards oscillations and concussions, as the common cars run on the 4 ft. 8½ in. gauge, can be fixed exactly.



A being the position of the centre of gravity in the 4ft. 8½ in. gauge cars now in use, and C D representing the distance between the centres of the rails or about 4 ft 10½ in., if B is the position of the centre of gravity of the cars of reduced dimensions, we have only from B to draw two lines B E and B F parallels to A C and A D, and the line E F will represent the distance between the centres of the rails of the gauge on which the small cars could run with the same angle of stability as the large ones.

All lines drawn from B, such as B H and B I, and striking the line C D in points H and I, outside of the points E and F, will fix on the line C D, the position of rails on which the small cars could run with a greater stability than the large ones. All lines, such as B G and B K, striking the line C D in points G and K, inside of E F, will fix the position of rails on which the small cars would run with less stability than the large ones.

For fixing the reduction of the gauge, when the reduction in dimensions, weight, and capacity of cars has been made, it is therefore important to know the position of the centre of gravity of both large cars and small cars.

As regards the stability of the narrow-gauge cars on the road, Messrs. Jackson and Sharp announce that these cars have been drawn at a speed of 40 miles per hour by locomotives (built at the celebrated Baldwin Works of Philadelphia) and have encountered gales, whose severity is too well known to travellers in the Colorado Uplands; in fact no effort has been spared to put them to the severest test. Their success under such circumstances fully insure their future performance, and demonstrates that the gloomy doubts entertained by many minds, respecting narrow-gauge rolling stock were utterly without foundation, and worthy only of a past age.

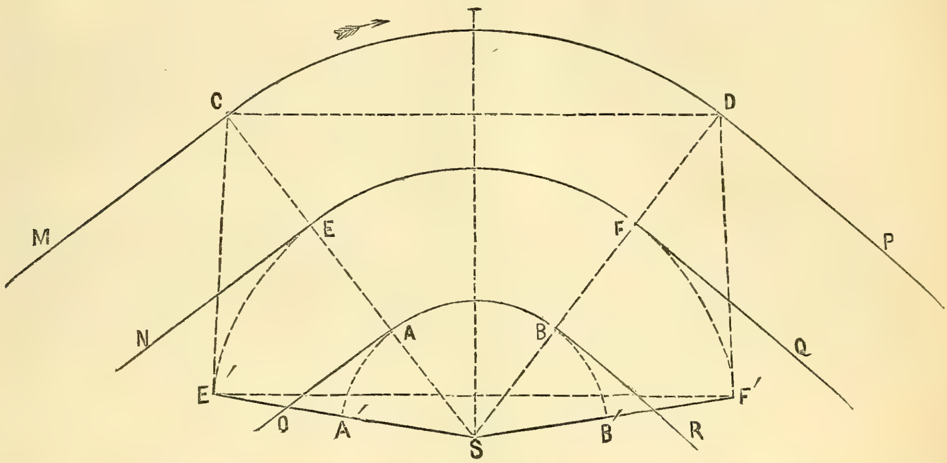
The saving of dead weight per passenger is about 300 lbs. An equal degree of speed is attainable and equal safety; and from the shortness of the axles, the wheels slip less on the outer sides of curves. This diminishes the correspondent twisting force applied to the axles, which is known as the "torsion strain," which, as is well known, destroys the fibre of the iron, makes all car axles useless after a time, and causes numerous railway accidents. Let Mr. Post, who made that subtle but erroneous and merely theoretical demonstration on curves at the end of Mr. S.'s pamphlet, bear that in mind, and answer the practical facts announced by Messrs. Jackson and Sharp. General W. S. Rosecrans, in a letter on the subject of narrow-gauge railroads, goes into some interesting calculations, which show that if the railroads in the United States, down to the end of 1867, had been built on the narrow-gauge plan, the saving in first cost would have been $480,000,000; the annual interest of which is, at 6 per cent., $28,800,000; that the annual saving on haulage would be $100,800,000; in all, an annual saving to the people of the United States of $129,600,000.

He shows further, that a much greater saving is in question for the future; for, he reasons, provided the whole country is to be as well furnished with railroads as the State of Ohio, there will be a total length of 165,800 miles of railroads; and the annual saving on this length of roads on the narrow-gauge system would be $547,540,515; which would pay off our present national debt in about five years.

Moreover, he shows that railroads, on the average, add $10 an acre to the value of the lands within 10 miles of them; the narrow-gauge roads can be afforded in districts where broad-gauge roads could not, to an extent which it is moderate to call 30,000 miles, which would add to the value of the land bordering these roads, $3,800,000.

Let us say now a word about the demonstration of Mr. S. S. Post in relation to the comparative resistance upon railway curves of different gauges annexed to Mr. S.'s pamphlet. Just at the very beginning the author makes a mistake in supposing that the width necessary between the two tracks of a narrow-gauge is the same as is necessary between the two tracks of a broad-gauge road. This would be true if the narrow-gauge cars were as wide as the broad-gauge cars, but as they are narrower, it follows that the width between the two tracks on a narrow-gauge can be reduced by just the difference existing between the width of the two systems of cars—the space left between two cars opposite, one on each track, being the same on the narrow-gauge as on the broad-gauge road. This is one of the principal advantages of a narrow-gauge when a double track is laid. To the economy of the single road-bed as compared with the wide-gauge single road-bed, we add the economy of saving in the total width of the double road-bed a quantity equal to the difference between the width of the narrow-gauge cars and the broad-gauge cars. This is what Mr. S. and Mr. P. both overlook. But the demonstration of Mr. P. is false from beginning to end. In it he supposes the narrow-gauge car to be of same length as the broad-gauge car, which is a misrepresentation.

To make a fair comparison, it ought to be supposed that the forward axle E A of the forward truck of a narrow-gauge car in leaving the straight track N E, O A, to enter the curve E F A B in the position E A, and after having run through the curve, is in the position B F, ready to take the straight track F Q, B R, and also that the forward axle of the forward truck of the wide-gauge car passes from the position C A to the position B D, ready to take the straight track D P, B R. Mr. Post in a very unfair and erroneous way, assumes that the forward axle of the forward truck of the narrow-gauge car has, in order to pass from one tangent to the other, or from one straight track N E O A, to the other straight track F Q B R, and through the curve A B E F, to start from the position E′ A′, and stop in the position B′ F′, the points E′ and F′ being determined by the intersection of the two parallels C E′ and D F′ with the curve of the outer rail of the narrow-gauge track,



and this on the wrong hypothesis, that the length of the narrow-gauge car must necessarily be the same as that of the broad-gauge cars.

The inspection of the figure and the positions of the points E′A′ and B′F′, which ought to be on the straight line and are out of it in an impossible position, shows the fallacy of Mr. Post's demonstration.

Now, I claim that the wheels will have to slip more from C to D than from E to F, and I claim also that the friction when the wheels slip is considerably greater than when they are rolling. That consequently on the outer rail C D of the broad gauge the wheels will have a greater friction and for a longer distance than on the outside rail E F of the narrow gauge, and that consequently the friction or resistance on the narrow gauge will be less than on the broad gauge, and as I have said before, the torsion strain, which is so injurious to the axles, will be less on the axles of the narrow-gauge car than on those of the broad-gauge car.*

The above formulas, which are from standard authors, testify the least resistances are experienced by the narrow gauge.

Having disposed of the demonstration of Mr. Post, as I have, I think, disposed of the arguments of Mr. S, and shown

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*The curving of a railroad causes three different kinds of sliding friction.

The first is caused by the fixity of the wheels on the shaft. One of the wheels on the outer rail slides a distance equal to the difference of length of the two curves. The second is caused by the parallelism of the shafts, causing the wagon to slide on the rails, turning round its centre of gravity while changing direction.

The third is caused by the centrifugal force, which forces the flange of the outer wheels to be in contact with the outer rail. Of the second kind of sliding friction, which is very important in European countries, we will not speak, because in America it is prevented by using centre pins under the wagons and engine tenders.

Theoretically the centrifugal force is less than the resistance due to the friction of the wagons on the rails for ordinary speed, and for a radius of 500 yards the flanges of the wheels ought not to be much in contact with the rails, if the wagons were not jumping; but as this effect is always produced, the friction due to centrifugal force is for wagons expressed by the formula

$$f'' \frac{P+p}{g} \times \frac{V^2}{r} \frac{2c}{D} \text{ in which}$$

V = speed of the centre of gravity of the wagon.
D = diameter of wheel.
c = horizontal distance from the vertical passing through the centre of the wheel to the point where the flange begins to touch the rail.
f'' coefficient of sliding friction of the flange of the wheel, found to be equal to 0.25.
g = acceleration due to gravity.
$P + p$ weight of wagon.
r radius of the circumference described by the centre of gravity of the wagon.

The friction of the first kind mentioned, caused their fallacy, I will now say a word about the 3 ft. 6 in. gauge that General Buell and myself recommended to the Texas Pacific Railroad.

Let me state first that I consider that it would be much better for the Texas Pacific to have a 3 ft. gauge than to have one of 4 ft. 8½ in. But General Buell and myself think that 6 in. more added to the gauge would allow to give still more room and comfort to passengers, and would allow a better shipment of cotton and cattle. If, however, the question was between the 4 ft. 8½ in. and the 3 ft., I would say take the 3 ft.

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by the fixity of the wheels on the shaft is equal to $f\frac{2a}{r}$ in which

a = half width of track.

r = radius of the circle followed by the centre of gravity of the wagon.

f = coefficient of friction of the wheels on the rails, equal to 0.25.

For a wagon, the resistance is $f(P+p)\frac{a}{r}$.

($P+p$ representing total weight of the wagon.

From this formula it can be seen that the greater radius of the curve the less is that friction; also the smaller the gauge the less the friction.

Now there is a fourth kind of friction, which is due to the rolling of the wheels on the rails.

That resistance is equal to $R = f'(P+p)$ in which

R = resistance.

$P + p$ = total weight of the wagon.

P being the total weight of the wagon on the wheels, and p the weight of wheels and shafts.

f' = coefficient of friction, equal to 0.001 (one thousandth) for wheels of 33 inches diameter.

Consequently the coefficient of rolling friction is only 0.001 while that of the sliding friction is 0.25.

CURRENT OBSERVATIONS.

By Geo. H. Mann, C. E.

Written for Van Nostrand's Magazine.

The general purpose of current observations is the determination of the velocity and direction of flow of running water in connection with such special purpose as the gauging of the discharge of rivers, the location of bridges, the ascertaining of the influence of docks, piers, and dykes upon the flow of bodies of water, the projecting of plans for the improvement of rivers and harbors, and the development of systems of torpedo defence. In considering them, two classes may be properly distinguished.

1. For the determination of the velocity alone.

2. For the velocity and direction of flow.

The application of the first class is more especially the gauging of discharge, and as any of the methods under the second head can also be used for this purpose, those which are applicable to velocity alone will be first considered.

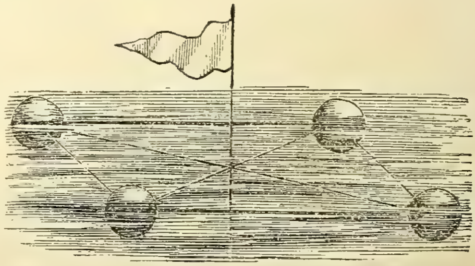
In computing discharge it is necessary to ascertain the mean velocity in a given cross section, and although this can be calculated from the surface velocity, it is generally necessary to determine velocities at the surface, at the bottom, and at intermediate points. For these, any of the following methods may be used.

1. By Floats.
2. By Woltmann's Mill.
3. By Pitot's Tube.
4. Hydrometric Pendulum.
5. By Impact Hydrometres.

For ascertaining the surface velocity, the simplest method is to note the time of passage of any light floating body, as a wooden ball between any two ranges at a known short distance apart; then

$$v = \frac{\text{distance}}{\text{time}} = \frac{d}{t}.\ a.$$

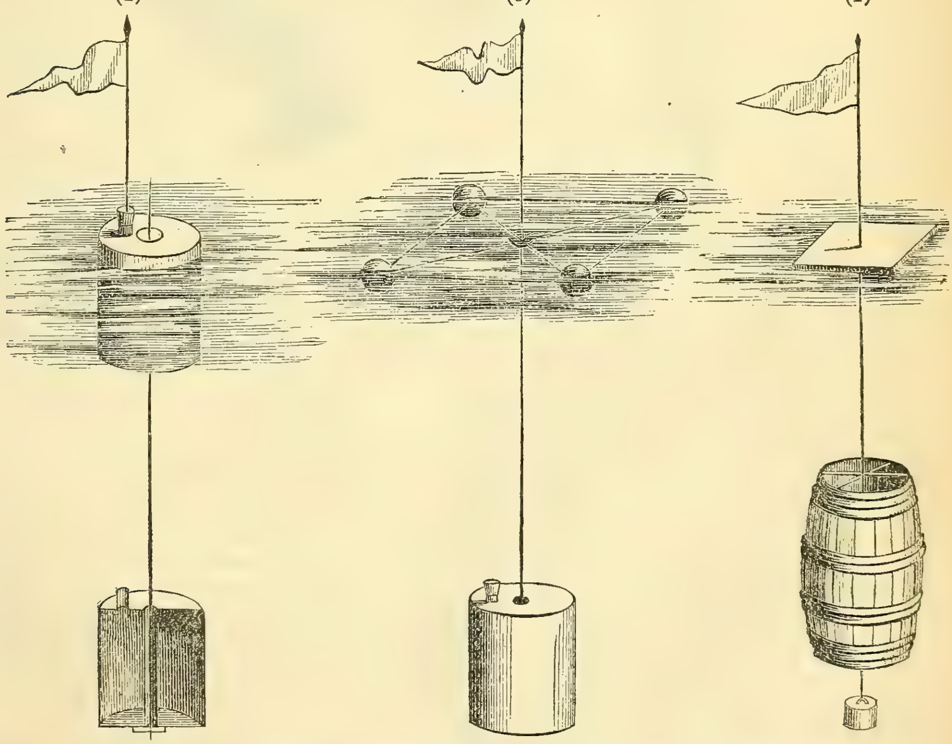
A good form of float, but little affected by the wind, and readily visible, is shown in the diagram. It consists of 4 hollow



rubber balls, united by a very light frame, supporting a thin rod and a flag, and so weighted as to almost submerge the balls. Brass balls from 4 to 12 in. diameter, and painted with light colored paint, may also be employed. By uniting 2 bodies, presenting equal surfaces to the current, by a thin wire, the velocity at various depths may be ascertained, one ball or body being weighted to sink and the other so as to allow the least portion possible projecting above the surface. Then, if we ascertain the surface velocity *bs*, simultaneously by a single float and denote the velocity obtained by using 2 floats by *vm*, we have for velocity at depth of second ball $bd = 2vm - vs$. By placing the lower ball at different depths we obtain the velocities corresponding to those depths, from a sufficient number of which we may determine the mean velocity. This can also be found by employing a floating staff weighted so as to float perpendicularly; it is conveniently made in short pieces which can be screwed together to adapt its length to the depth. The velocity at any particular depth is determined by having the submerged body present so large a surface that in comparison with it that of the surface float shall be inconsiderable, then by allowing the float to start some distance above the first range, so as to gain headway, we find the velocity at the depth of the submerged body. The forms of floats employed are so numerous that an attempt to describe all of them would occupy more space than the limits of this article will admit of. A number of them are shown in the diagram.

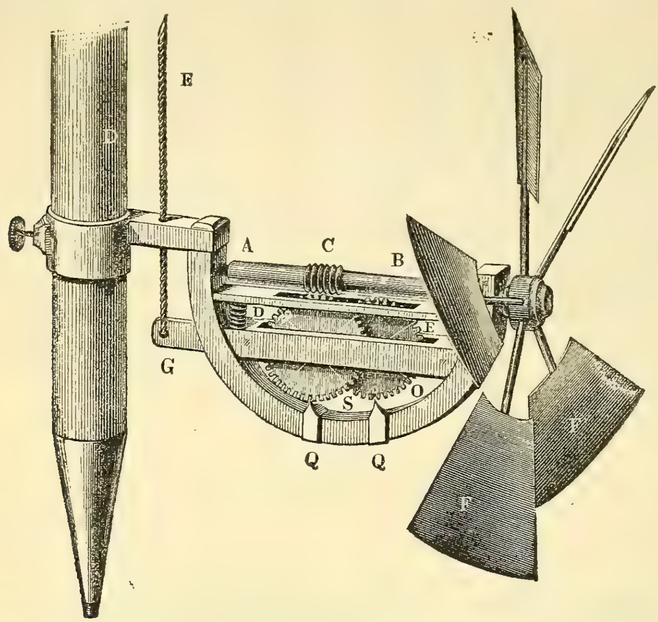
In (1) the lower float is a barrel with both heads out, weighted so as to float upright; (2) and (3) are very convenient forms, and consist of tin cylinders having a tube running down the axis so that the wire can be readily lengthened or short-

(2) (3) (1)



ened; a small orifice closed with a plug allows the admission of water for submerging them. The surface float of (3) while offering but little surface to the action of the current, has a broad base and is not readily overturned. For observations in salt water, copper instead of tin floats are preferable, as those made of tin corrode very rapidly. Wire should generally be employed to connect the floats, rope being apt to chafe off. For small depths, strong cord answers very well.

For the direct determination of the velocity at any point, the best form of hydrometer is Wollman's Mill or Tachometer, shown in the diagram. The instrument is attached to a pole so that it can be immersed to any depth. It consists of a frame supporting a shaft A B, having attached to it either a small propeller screw or from 2 to 5 vanes inclined to the direction of the axis at angles varying somewhat with the velocity of the current (a vane serves to keep it in the di-



rection of the current). For small velocities this angle, equal to the impact angle, should be about 70 deg.; it will be found advantageous to have several sets of vanes for varying velocities. When we immerse the mill in running water, and hold it in a direction opposed to the current, the number of revolutions of the shaft depends upon the velocity, and this measures it. By having a number of threads of an endless screw cut upon the shaft and working into the teeth of a cog-wheel D, we can, by means of an indicator and figures marked upon this wheel, ascertain the number of its revolutions, and by having another cog-wheel working into a pinion on the shaft of the first, a larger number of revolutions are registered. The gearing is kept from turning except during time of observation by having its shafts run in bearings upon a lever G, which is pressed down by a spring so that it is only by drawing the string E, upward that the teeth of the first cog-wheel take into the endless screw. In consequence of resistances, and from the fact that the number of revolutions is dependent upon the angle of impact, the number in a given time is not exactly proportional to the velocity of the water, so that instead of having $V = An$, in which n = number, V = velocity and a = a constant determined by experiment, we have

$$V = V^0 + A\,n \quad . \quad . \quad . \quad (1.)$$

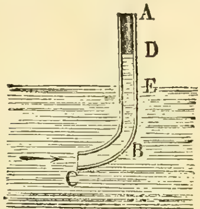
or more accurately

$$V = A\,n + \sqrt{V_0^2 + C n^2}\; V_0$$

denoting velocity just sufficient to start the mill, A and C empirical constants determined by experiment, as follows: The mill is placed in a current of water, whose velocity is known (either by observations with a float or by using a trough and making the quantity discharged and received equal, and measuring the discharge)* and

*In order to determine the velocity by measuring the water discharged from a trough under a constant head it is only necessary to get in addition the dimensions of the cross section at point of immersion; then we have $V = \frac{Q}{F\,t}$, in which Q = quantity, F area of cross section, and t = time. From these observations the constants may be the number of revolutions in a given time is noted, as many observations as possible being taken.

Pitot's Tube is a simple form of hydrometer, and consists of a bent tube, generally of glass, held so that its lower branch is horizontal, and opposite to the direction of the current. The column of water within the tube is forced up by the impulse of the current above the level of the exterior water; the rise is dependent upon the velocity of the water, and may be



used to determine it. If h= rise and c= empirical constant determined by experiment, then $v=c\sqrt{h}$. To find c we place the tube in water of known velocity v, then $c=v\sqrt{h_1}.\therefore c=\frac{V^1}{\sqrt{h^1}}$. For convenience in reading the height h, the instrument generally consists of 2 tubes, from one of which a pipe proceeds contrary to the direction of the current, and from the other, 2 pipes at right angles to it, then by closing both tubes at once and drawing hydrometer of the water the difference of heights can be easily read. The oscillations in the tubes may be obviated by making their mouths narrow. For velocities ranging from 1 to 4 ft., by using good instruments it has been found that $V=\sqrt{h}\times 11.5$ very nearly. Pitot's tube is an easy instrument to use, and under favorable circumstances gives very good results.

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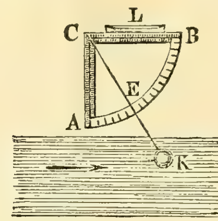
deduced by introducing values of V and n into (1) or (2) and forming equations of condition from which A and C V_0 can be found by combination, or using (1) we have by method of least squares

$$V_0=\frac{\Sigma(D^2)\,\Sigma\,(c)-\Sigma(b\,c)\,\Sigma\,(b)}{\Sigma\,(c^2)\,\Sigma\,(b^2)-[\Sigma(b)]^2}$$

$$A=\frac{\Sigma\,(c^2)\,\Sigma\,(b)-\Sigma\,(b\,c)\,\Sigma\,(c)}{\Sigma\,(c^2)\,\Sigma\,(b^2)-[\Sigma\,b\,c)]^2}$$

in which $b=\frac{n}{v}$ and $c=\frac{1}{v}$ Σ, denoting sum of all the values. It will of course be necessary to determine constants for each different vane wheel.

Hydrometric Pendulum.—This hydrometer consists of a graduated quadrant (see diagram) having attached to its centre a string or wire to which is fastened an ivory or metal ball. The angle between the vertical and the string when the ball is held in running water, depends upon the velocity. For the purpose of placing the zero line vertical, a level tube is put upon the instrument. An ivory ball is used for velocities less than 4 ft. and metal ones for greater velocities. If

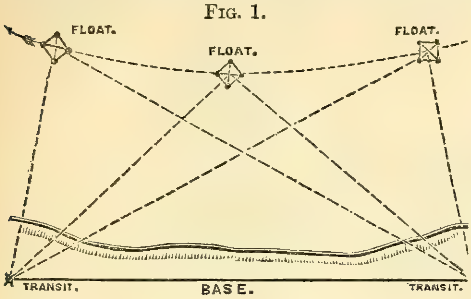


α = angle, we have $b=c\sqrt{\tan\alpha}$ in which c is an empirical constant determined thus: v = known velocity, α = corresponding angle; then $c=\sqrt{\tan\alpha_1}$. In addition to the hydrometer already mentioned, there are a number of others by which the velocity is ascertained. By measuring by a balance the force of impact upon a surface, the general equation for the velocity is $v=c\sqrt{I}$ in which I = impulse and c = constant dependent upon area of surface. There may be mentioned more as a curiosity than anything else, Leslie's hydrometer, by which the velocity is ascertained by observing the relative rates of cooling of the bulb of a delicate thermometer. We can also determine velocity by immersing a box with a small hole in it, allowing the water to flow in for a certain time, closing it suddenly and comparing with the quantity admitted in the same time in a stream of known velocity. We may determine velocity from the formula $V=\frac{Q}{C}\sqrt{2gh}$, in which Q = quantity, C = empirical constant determined by experiment as before. Thus $C=\frac{Q_1}{V^1+\sqrt{2gh}}$, in which g=acceleration due to gravity, and h = depth of orifice below surface, C being dependent on the co-efficient of discharge and upon the connection of the orifice.

2. *For determining velocity and direction*, either free or restrained floats (logs) may be used. The various forms of free floats having been described in the pre-

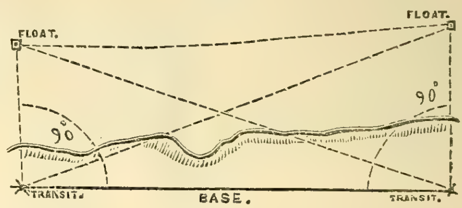
vious section, the methods of using them will now be given. If the observations are to be made where the floats are readily visible from the shore, a base or bases of convenient length should be measured as nearly as possible parallel to approximate direction of the current, and an observer with a transit located at each end, the float being allowed to drop down with the current, its positions are located by measuring simultaneously at each station

Fig. 1.



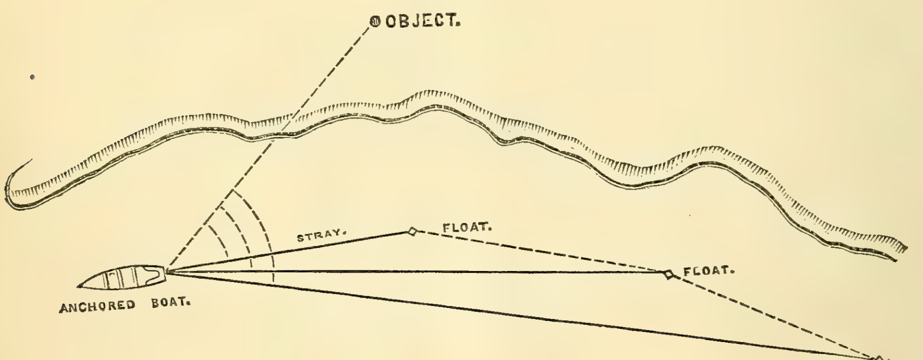
angles between it and the other station; these angles may be taken at equal intervals of time, or the time and angle between the base and float may be taken by each observer when the float crosses a line perpendicular to the base at the other station (see Fig. 1). When the current is rapid the latter (Fig. 2) method may be advantageously employed; the velocity being determined from plotted positions of floats $b = \frac{\Sigma D}{\Sigma t}$ D = distance, t = time.

Fig. 2.



When a base on land cannot be used 2 boats may be anchored to form a base and the positions of the float located by observations with 2 sextants, the position of the boats being determined by measuring angles from each to 3 known points on the shore, or by angles measured with a transit ashore; the bearing of the base and its length measured as nearly as possible by a tightly stretched cod line being taken as additional data. Should it be necessary to take observations when no land is visible, the position of one boat

Fig. 3.



must be determined astronomically, and the relative place of the other found, although in such a case restrained floats or logs are generally employed. Another method is to start the float from some known point marked by a buoy and follow it with a boat, locating its position at equal intervals of time by sextant observations upon 3 points ashore. In using *restrained floats* the boat is anchored and located with respect to the shore, and as the station is likely to be occupied more than once it should be marked by a barrel-buoy whose anchor warp has but little slack. In all observations at equal intervals of time a sand-glass should be employed, especially if the interval is small. To an ordinary ship's log, or preferably to any of the forms of floats given in a previous section, is attached an ordinary log line passing to a reel in the boats. The line, before using, should be wetted and stretched. It should then be marked off into miles and fractions of a mile, as follows: If we use a 30-sec. glass, a velocity of 1 statute mile per hour will run out the line

$$\frac{3600^s}{30} \times 5280 = 44 \text{ ft.}$$

or of one nautical mile,

$$\frac{3600^s}{30^s} \times 6087 = 50.72 \text{ ft.}$$

These divisions of the line are best marked by knots made in white cord and fastened to it, or thus: 0 is marked by a small strip of leather—1 mile by a strip with a hole in it and so on, making a hole for every mile, then the tenths are marked to 5 by knotted cord, $\frac{5}{10}$ a small red rag and then knots up to 1 mile, or the line may be divided into feet. About 60 ft. of *stray* should always be left before commencing to mark the line. Having run out the *stray*, the time is noted and the angle between the float and some fixed object whose position is determined, is taken by the sextant; after allowing the float to take out the line for the given interval, the distance run out is noted and also the angle between float and object is taken. This may be repeated at the end of every interval until the marked line is all run out. (See Fig. 3.)

In tidal waters, simultaneous observations should be taken at tide gauges in connection with the current observations for the purpose of reducing the velocities as observed either to their proper tidal hours, or to velocities corresponding to some fixed plane.

THE CAUSES OF EARTHQUAKES.*

By AUGUSTUS LE PLONGEON, M. D.

Written for Van Nostrand's Magazine.

1. WHAT IS THE CAUSE OF EARTHQUAKES?

This is a question of more than ordinary importance, since it has occupied the minds of philosophers in all ages, in all countries. It is a question that has been much debated in academies and other temples of learning. And still it remains a puzzle to the learned men of our modern times.

The ancient philosophers seem to have been far ahead of us in this particular, as in many other branches of knowledge; for while they were able to predict days—nay months—in advance of the occurrence of our mother earth's convulsions, and warn their contemporaries of the impending danger, those possessed of the greatest scientific attainments in our age, are unable to recognize the premonitory symptoms and announce to the world the time when, and the place where an earthquake is to take place—notwithstanding they can read in the atmosphere all the meteorologic perturbances which occur, and prognosticate the storms and other phenomena which these changes foreshadow.

Many are the theories, quite antagonistical some of them, that have been launched on the vast ocean of speculation. All of them, no doubt, more or less plausible, resting on some scientific fact or other, have met with opposition. All have been impugnated, proved inaccurate and faulty. None has unveiled the hidden truth; and the mighty problem stands yet unsolved.

Facts are certainly not wanting to serve as milestones on the road of inquiry. And the laws that govern every phase of the phenomenon, well known to the wise men of our days, if properly applied, will cast their bright light, and illuminate the darkness that hangs over it.

Geology teaches us that, from epochs lost in the deep abyss of time, the earth has quaked; and natural philosophy, together with the discoveries of vigilant scrutinizers in the arcana of nature, have told us of the laws that govern these various manifestations of its wonderful vitality, and taught us that motion is life, and life is forever and ever.

Why, then, it may be asked, are the causes of earthquakes yet a mystery? Simply because we have entered the study of these phenomena, surrounded by the preconceived ideas, the prejudices and bias, either scientific or religious, that had been inculcated in us by the teachings of our predecessors, instead of stepping into the sacred precincts of the great temple of

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nature, our minds free and unshackled from all prepossessions, ready to receive the revelations of the mighty arcana with candor and good faith.

I do not pretend to be wiser than any of the learned men who have investigated the subject, for I am the last among the worshippers of science. But having studied the phenomena in the midst of the terrible convulsions that have shaken the American Continent to its very basis, of late, and applied the different facts that I have observed during many years' residence in countries subject to earthquakes, to the touchstone of the natural laws that govern their manifestation, free from all undue bias, either scientific or religious, I have tried, from my observations, to draw all possible reasonable and scientific conclusions.

It is the result of patient and careful investigations that I humbly submit to your criticism in this cursory article, with the hope that it will meet with your approbation.

I have said that :

The Ancient Philosophers were acquainted with the Cause of Earthquakes.

This might be considered a bold assertion on my part, if I had not their writings and those of the historians of antiquity to back me up.

We all know that the wanton destruction, by fire, of the 700,000 volumes of the library of the Temple of Serapis, has deprived us of the knowledge of the scientific truths discovered by the wise men of antiquity. The few works, however, that have escaped the fanatical wrath of the ignorant Mahometan chieftain, and the deplorable hastiness of the Roman general, manifestly show that the philosophers of old had indeed given their earnest attention to the study of the very question we are about to elucidate ; and that, owing to their diligent inquiries, and their knowledge of the laws that govern the phenomena, they had discovered some of the causes, if not all, of the earthquakes. We read in Philostratus, that Anaxagoras, who was thoroughly instructed in the science of the Egyptians, foretold the falling of stones from heaven, and that there should be an earthquake, *in consequence of the mud which he perceived on the surface of the wells.*[1]

1. Philostratus—"Life of Apollonius," Book I., chap. ii.

Marcellinus[2] asserts the same thing, and so does Diogenes Laertius. Apollonius gave it as his opinion that the earth was composed interiorly of a mixture of bitumen and sulphur in a constant state of incandescence, and when a current of air penetrated the chinks and caverns, a fire was kindled, a flame was produced that burst out from the mountains, and streams of liquid fire; this being the cause of volcanoes and earthquakes.[3]

Jamblicus[4] tells us in his "Life of Pythagoras," that Pherecides, merely by testing of or looking at the water drawn from a well, advised the inhabitants of Samos to put themselves in safety, for they were threatened with an earthquake, which, in reality occurred.

Pausanias,[5] in his "Itinerary of Greece," whilst pretending that the earthquakes are phenomena produced by the anger of the gods, enumerates, however, the signs by which they are preceded and foreshadowed. Among these he mentions the water in the wells becoming turbid and emiting fetidity.

Pliny, the Elder,[6] in his Natural History, after speaking at length upon the subject of earthquakes, endeavors to imagine means to prevent the phenomenon, and gives it as his opinion, that to some extent it might be hindered by boring very deep wells in the countries where they are of frequent occurrence.

This same author, in another chapter[7] of the same work (and Cicero,[8] in his "de Devinatio," concords with him), says that Anaximunder foretold to the Lacedemonians, not only an earthquake, but also the falling of the summit of the Taygetus, a mountain of Lacona. The event confirmed his prediction.

In the XIII century, a monk, in order to oblige the Emperor Andronic to recall from exile the patriarch Athanasius, threatened him with divers plagues—with an earthquake among them. The earthquake really occurred in Constantinople within 3 days after the prediction ([9]).

The illustrious Buffon ([10]) speaking of

2. Ammionus Marcellinus, Book XXII., chap. xvi.
3. Philostratus—"Life of Apollonius," Book V., chap. xvii.
4. Jamblicus—" Life of Pythagoras," Book I., chap. xxviii.
5. Pausanias—"Itinerary of Greece" (Achaic, chap. xxiv.)
6. Plinius—" Natural History," Lib. II., chap. lxxx.-lxxxi.
7. Ibid , chap. lxxix.
8. Cicero—" De Devinatio," Lib. I., chap. l.
9. Pachymer—Lib. X, chap. xxxiv.
10. Buffon—Natural History, Art. XI. On the proofs of the theory of the earth.

the proofs of the theory of the earth, relates that at Bologna, in Italy, in the year 1695, everybody saw with great surprise the waters becoming turbid 4 hours before an earthquake.

Agathino Longo ([11]) in an historical and physical memoir on Earthquakes asserts that an identical phenomenon took place a few days previous to the earthquake that was felt in Sicily during the month of February, 1818.

Does not Mr. Cadet de Metz ([12]) in his Natural History of Corsega tell us that after having observed during the month of December, 1782, very dense sulphurous vapors covering the plains of Calabria Citeriore, he came to the conclusion that an earthquake was near at hand, and predicted the catastrophe which took place at the beginning of 1783.

And lastly did not Senor Vidaure, ([13]) a learned Peruvian, on hearing certain subterranean noises of a peculiar character, predict 4 months in advance, the earthquake that destroyed a part of Lima, in 1818.

And I, myself, ([14]) predicted 6 months in advance the terrible earthquake that on the 13th of August, 1868, laid to the ground the strongly built city of Arequipa, and many others in the southern provinces of Peru.

Will you reject the testimony of so many writers and historians? Will you say with Cicero: The thing is impossible? No, I am sure—for as a scientific man you know that the arcana of nature become unfolded to our gaze more and more every day; you know also that every day some of the laws that govern its phenomena are discovered, and that nothing is impossible to the human mind in the scope of discoveries and scientific investigations.

Impossibility is the by-word of ignorance, unknown among us, the worshippers of science.

2.—THAT THE CENTRE OF THE GLOBE WE INHABIT IS NOT LIQUID FIRE

is generally admitted by most of the scientific men of our age. It does not enter within the limits of a cursory article like this to enumerate all the facts that can be adduced to prove that it is most probably a compact mass of metals and minerals, with a rather thin crust of oxides to cover it. I say thin, comparatively, of course. But to prove it I will merely speak of the heat that has been observed to exist in the different strata where man has penetrated; I will try to show that this heat is simply superficial and influenced altogether by different causes than central fires.

It is a fact demonstrated and proved that electro-magnetism is the active agent that produces all the phenomena of life that takes place at every moment of time before us, continually changing and producing new beings and new species of being. I consider that electro-magnetism is the life of this immense living body on which we exist as parasites; and that in the same manner as heat is developed in the human body through electro-magnetism's agency, which causes the blood to flow rapidly, and circulate with force, throughout the entire system, producing thereby a continuous friction, in each and every of its parts, engendering what is termed *animal heat* — this being greater where there is greater affluence of circulating fluid, and therefore a greater friction—so also are the same electro-magnetic agents the source of the internal heat of the earth. How far this internal heat reaches toward the centre, is unknown, and will most probably remain unknown forever to man.

The laws of nature are as simple as they are immutable. When studied, we find that they act alike in all things, advancing from the simple to the complex. We find nature very economical of the means employed by her to produce her creations, and most prodigal in the variety of those.

Let us take her for our guide and proceed from the simple to the complex.

The science of electro-magnetism is a comparatively new one, which will eventually lead to great discoveries, and give us the explanation of many phenomena that to the present day have remained unexplained.

The heat seems to augment progressively as we descend towards the centre of the earth. But the progression is not constant. At places the heat increases rapidly, at others very slowly. This difference has for a long time puzzled geologists. At last they have come, not to a definite, but an approximate conclusion,

11 Agathino Longo—Biblioteca Italiana, Settembre, 1818.
12 Cadet de Metz—Natural History of Corsega, pp. 138-147.
13 Vidaure—Moniteur Universel, 27th of August, 1823.
14 Le Plongeon—Jesuits and Peru, p. 482.

by admitting that the heat increases 1 deg. for every 27 metres. Beudant pretending, however, that it augments 1 deg. for every 33 metres, on every point of the globe. But such is not the case, for there are, perhaps, not two places, even in the same locality, where the heat is the same at the same depth.

However, for the sake of demonstration, let us admit it is so, and that the heat increases progressively 1 deg. for every 33 metres we approach nearer to the centre of the planet. What will then be the consequence? At 3,000 metres the heat will be sufficient to cause the water to enter into ebullition. At 20,000 metres, the supposed thickness of the crust of the earth, all silicates will melt. At 80,000 or 100,000 metres, all metals, even the most refractory, will be in fusion; the diamond volatilized.

As the semi-diameter of the earth is 6,366,000 metres, the heat at the centre will then sum up the prodigious amount of 250,000 deg. of heat. Think of it—250,000 deg. Can you imagine such heat and not be yourself volatilized instantaneously.

Can any man with common sense ever believe such nonsense? Why, Beudant himself is surprised at the awfulness of the offspring of his own science, his pet frightens him, for in his "Course of Natural History" he tells us: "That if anything is capable of astonishing anyone, it is that no more catastrophes should take place in our days on the surface of our planet, particularly when we consider the enormous disproportion which exists between the diameter of the melted matter and the crust of the earth, which is only 20,000 metres. This thickness is but very small when compared to the terrestrial radius, which is more than 6,000 kilometres. On a globe of 1 metre it would be represented by 3 millimetres approximatively. That would not be the thickness of a sheet of paper on one of our ordinary terrestrial globes."

These are, verbatim, the words of the savant geologist. Yet, there is another thing that astonishes me more than that; it is that a man of his acknowledged science, if he calls himself sane, can possibly cherish and seriously advocate such an idea, now that we are perfectly conversant with the laws which govern the expansion of gases, and those which regulate the march, attractions and gravitation of celestial bodies; and Mr. Beudant knows, certainly, as well as ourselves, that only a temperature of 12,000 deg. is required to volatilize all and everything known to man on earth. If his theory was true, at 320,000 metres under our feet there would be nothing but gases floating on an immense furnace of 238,000 deg of heat to expand them more and more, and a very thin shell of 20,000 metres to contain them and resist the immense pressure caused by their increasing expansion.

Who, in the name of common sense, will admit of such an absurdity?

There is no central fire; there cannot be. What does the science of the skies tell us on the particular? Listen!

We all know that the astronomers, in order to calculate the course of the celestial bodies, are obliged to know exactly their weight and volume. They, of course, had to determine that of the earth, in order to compute its motions in space, and its relations with its other companions and co-travellers. Their computations have been so accurate that they can determine the exact time of the apparition of comets. When eclipses, conjunctions, etc., etc.. are to take place, by the astronomical observations, taken four or five thousand years ago by the Chaldean and Egyptian priests; by those of the ancient Chinese astronomers, as that of the eclipse of the sun, mentioned in the "Chou-King," which took place during the ninth month of the year 2159 B. C., all of which within the last century has been proved perfectly correct. We have come to the knowledge that no variation whatever has taken place, in the volume of the earth at any rate, from those remote times to our days. If the planet had contracted, as some pretend, the rapidity of its rotation wonld have necessarily increased, and such is not the case.

The natural corollary of all these astronomical observations is that the computations of the astronomers being correct, the surmises of the geologist as to the central fires and their effects are all imaginary. But you may, and very appropriately, tell me, that, as far as men have penetrated into the earth, they have found heat increasing, and then you may ask me:

3. WHENCE THE HEAT EXPERIENCED ON THE SURFACE AND IN THE INTERIOR OF THE GLOBE?

I will answer.

I told you that I consider the earth as animated, a living being, living out its own life among its brothers and sisters of the immensity, just as any one of us among our fellow-beings. That, as we have our soul, which gives life, activity, and warmth to our bodies, so has the earth its soul, that gives it life, activity and warmth, that animates all things existing in it or on its surface. I told you that this soul is *electro-magnetism.*

I do not suppose that any scientific man will dispute me, that electro-magnetism is the agent of the attraction that celestial bodies exert upon each other; and this is the cause of their motions through space. Nor will any one deny that motion causes friction; that in its turn engenders heat and light; that electro-magnetism causes the cohesion of all the molecules whose aggregate composes the universe is a well admitted fact. It is, therefore, the *life-sustainer,* the SOUL of the whole creation, of which our reduced planet is but one of the smallest atoms.

I have said that electro-magnetism was the agent that produced the heat of the earth. Let us see if my assertion is sustained by FACTS; for only through the observation of *facts* and a clear unprejudiced mind, can we compare them together and arrive at the knowledge of their causes, and to the causes of these causes that form the catenation of the natural laws, whose understanding and interpretation is science.

1st. The earth swims in a medium—a universal fluid that fills all space. Call it by whatever name you please—ether—cosmic fluid—imponderable fluid. This something is obviously matter under a certain form. It has been asserted to be composed of 64 elements that Graham has classified into 6 series or classes. This something, being matter, offers resistance, and opposes the forward motions of the bodies that pass through it. Of course it opposes the forward motion of the earth in his movement round the sun, and through the immensity where it follows this body in its rotary motion around an unknown centre. This resistance not only causes the diurnal rotation of our planet; its conical movement, which it accomplishes in 25,868 years; its vibratory motion that produces the phenomenon known as tides; but also as the earth forces its way through the universal fluid at the stupendous rate of 30,550 metres per sec., besides the 464 metres per sec. of her diurnal rotary motion, a large amount of continuous friction is produced throughout its whole surface, but particularly at the equator, where the globe is larger. Friction, anywhere and everywhere, creates heat. It is, therefore, impossible to doubt that this is one of the causes that produces heat at the surface of the earth. That heat so generated during countless ages has progressively and steadily permeated its superficial strata, and is preserved in the inferior ones, not exposed to the external causes of refrigeration, like those above, is obvious, and men find it there when they penetrate into them.

It might illustrate my proposition by the example of the cannon-ball, that when discharged from the cannon's mouth, is cold, but after having traversed the air at the rate of 500 or 600 metres a min., is very hot at the time it reaches its destination; but the process of refrigeration begins from the surface toward the centre; and if we split it we find that the interior is yet hot while the external parts are quite cool. What is our reduced planet but a very small cannon ball, that has become heated traversing the cosmic matter, since centuries, at the frightful rate I have just mentioned?

2d. The rays of the sun are another cause of the heat of the earth. These rays are not hot; certainly not, the snows that eternally cap the highest mountains, prove it. How then can they impart heat, if they are cold? Oh! electro-magnetism again is at work there! It is true that the rays of the sun do not convey heat, but they carry light. Light puts in motion the molecules that compose the atmosphere. They rub one against the other, there is friction; friction engenders heat—the atmosphere in its lower strata being more dense, the friction is greater, consequently more heat is evolved and communicated directly to the surface of the earth. It penetrates its lower strata and there is preserved as already stated, increasing the intensity of that produced by the first cause.

It is not relevant to prove how the rays of the sun carry light through electro-magnetic agency. The electric lamp of Servin is a good illustration of how electro-magnetism engenders light. The sun, immense reservoir of electro-magnetism, we may consider as the positive coal of Servin's lamp—the earth, another reservoir, but smaller, the negative coal; the light produced is in proportion to the distance of the two poles.

"All bodies," says Mr. Jacobi, of St. Petersburg, "are magnetic in a larger or smaller degree. The earth is a vast magnet, and so are, without a doubt, the other planets, their satellites, and the sun itself."

Then the rays of the sun, acting through or rather produced by electro-magnetism, are another cause of terrestrial heat.

3d. The internal heat of the earth is also due to the immense chemical operations constantly going on under the agency of electro-magnetism, at no great depths, insignificant even if compared to the supposed crust of the planet.

This, as far as we know, is a vast conglomeration of metallic and mineral matters, which in order to combine, only need the action of an agent. This agent is electro-magnetism. For, as says the translator of Lyell's Geology: "It would be a great error to believe that the action of electricity is powerful only when noisy and sudden. Its tacit and quiet action throughout nature is far more important. It extends its influence in nearly all combinations. *The chemical affinity itself does not seem to be but a variety of electrical attraction.* And since the constant reunion and the quasi-identity of the electrical and magnetic fluids has been demonstrated; since the phenomena of the magnetic needle, those of the thunder, of the electric fluid in the air, and its dispersion, find an explanation in the action of electro-magnetism, *well may we presume that electro-magnetic currents circulate in the interior of the globe ; and indeed, experiments performed on the electro-magnetic properties of metalliferous veins, have led to the discovery of marks and vestiges of these currents in the interior of the earth.*"

We all know that chemical combinations, decompositions, and recombinations take place incessantly in the vast laboratories of the earth. These operations are nothing else but the result of the action of electro-magnetism on the molecules of matter. These are in continual motion. During their travel they evolve heat, in consequence of the perpetual friction they are subjected to. Hence the chemical operations going on in the interior of the planet are another and third cause of its heat ; and the life-sustainer, electro-magnetism, the agent.

4th. The oxidation of metals is another cause of the heat of the earth.

It is a truth known and demonstrated that currents of electro-magnetism traversing metallic bodies, produce oxidation.

The earth, or at any rate that portion explored by man, is a conglomeration of mineral and metallic bodies. These are constantly traversed by electro-magnetic currents. Oxidation then takes place incessantly and produces an augmentation of temperature. Slow, it is true, but constant.

Leaving aside all imaginings, which should never be invocated in the elucidation of scientific questions, as it has unhappily too often been the case in the very one under consideration, I will try to co-ordinate the truths enunciated, and direct their light into the darkness that surrounds the mystery of the earth's convulsions, and try to discover the part they play in

4.—THE PRODUCTIONS OF EARTHQUAKES AND VOLCANOES.

What are volcanoes? Are they the safety valves which prevent our poor little planet from bursting like a bomb and sending us flying towards the skies, as some pretend ?

This question I will answer by another. Who would ever imagine to inquire if the boils, that sometimes, under the influence of certain pathological conditions, appear on the human body, are the safety valves, intended by nature to prevent the explosion of that body ?

If there are no central fires; if it is mathematically, scientifically, nay, materially impossible there should be any, what is the use of vents or valves ? If the planet is a solid mass, what danger does it run of exploding ?

But let us suppose, for an instance, with Buffon, Zimmermann, Humboldt, Cuvier, La Place, Beudant, and many other illustrious defenders of the existence of an internal ocean of fire, whose burning waves sweep, ebb, and flow against the walls of the thin shell on which we live in imminent danger, and examine if the volcanoes can be the vents of that immense furnace.

Our first step will be to ascertain the number of volcanoes and the size of their craters.

Geographers tell us that there are 163, the positions of which are perfectly known; 67 are on continents, 96 on islands, adding this most singular fact, that none of these situated on continents are at a distance exceeding from the sea, more than 75 miles in an air line—a peculiarity that I commend to your attention.

Humboldt asserts, that they number in all 223—all active; Keith Johnston declares that there are 270—190 on islands, 80 on continents.

Never mind what these authors say about the number of volcanoes; I will grant that there are many more they knew nothing about. Let us be generous and double the number, so as not to be accused of trying to crawl through a small hole. We shall say there are 550 vents or safety valves, if, by and by, volcanoes prove to be such.

Our next step will be to ascertain the size of the chimney or crater of these vents.

Geographers again tell us that the crater of Vesuvius, one of the largest known, is 2,000 metres in circumference. Let us continue to be generous, and say that the average opening of all the craters is 3,000 metres in circumference. One thousand in diameter, the $\frac{1}{20000}$ part of the supposed thickness of the terrestrial crust. That is admitting that the chimney is of the same all the way down.

What is a hole of 1,000 ft. in diameter compared to the whole surface of the globe? It is not even as much as a hole made on one of the terrestrial spheres in use in our common school, with a fine cambric needle.

Now, by way of illustration, and in order to keep all due proportion, let us suppose one of these globes to be one metre in diameter, hollow, made of the most refractory metal—say platina—the thickness of which, in order to correspond to the thickness assigned to the supposed crust of the earth, would be 3 millimetres. We shall proceed to bore on the surface 550 small holes with a fine needle. These will represent the volcanoes or safety valves. After these we shall introduce into it, through an opening left for the purpose, to be afterward closed and the covering solidly consolidated, so as to present the same amount of resistance as the balance of the surface—two parts of filings, one and a half part of pulverized sulphur, and a sufficient quantity of salted water to make a soft paste. When the chemical decomposition will take place, and the heat so intense as to melt the whole mass into sulphuret of peroxide of iron, the water will have been converted into steam, this again into gases, do you imagine that the 550 little holes or safety valves will permit a sufficient quantity of steam or gases to escape, and prevent the apparatus from bursting? Will even any steam or gas escape through these little openings?

Any unprejudiced mind will say no. Then how can the 550 volcanoes that we have supposed to exist on the surface of the earth be considered any longer as the safety valves of the great liquid heart, said by some geologists to occupy the centre of the planet?

Their assertion cannot stand the touchstone of science. And the truth of our denial is the more obvious, if we take into consideration that not $\frac{1}{10}$ of the known volcanoes are in activity; and that those which are active do not continually throw out lava; which they would, if connected with the central furnace.

From all that I have just said I think I may safely deduce that the volcanoes are not the safety valves of the earth, but mere local accidents on its surface, just as boils are on the human body.

There is another remarkable fact connected with the existence of volcanoes. It is this. That all volcanoes, without an exception, have for a base, and are situated on, primary formations; showing that the combination of porphyric or granitic rocks with the metallic veins found in them is the only capable of giving birth to volcanoes, through the agency of the electro-magnetic currents that traverse them. It is out of the limits of this article to enter into a nomenclature of all the substances found in the superficial strata of the planet, whose nucleus seems to be formed of granite, syenite, protogine, diorite, pegmatite and porphyry, crossed in every direction by metallic veins.

It is well known that whenever two or more of these mineralogic and metallic substances are put in contact and thoroughly wetted with salt water, a chemical decomposition takes place evolving heat the—more extensive the decomposition the greater the amount of heat.

It may even reach incandescence under certain circumstances; such, for instance, as the influence of the sun or other celestial bodies, that, acting one on the other as powerful magnets, engender immense voltaic arches, scatter throughout the boundless fields of creation, light and heat.

Then wherever a large quantity of these sustances has accumulated, there will be a large amount of heat developed, which under proper conditions will give birth to a volcano. This is also one of the causes of the multitudinous variations that are observed in the temperature of the divers parts of the earth, even at the same depth.

It is a fact very evident, that if that heat had its source in a central fire that would emit an inconceivable quantity of caloric, the thin crust would be equally heated, even to the top of the highest mountains; seeing that the Guarisconkar, in the Himalaya, said to be with the Illimani and Sorata in Bolivia, the highest peaks of the globe, is only 9,000 metres in height, that is to say, the fourteen-hundredth part of the earth's diameter.

5.—ARE THERE ANY MEANS OF DETECTING THE PLACES WHERE SUCH ACCUMULATIONS EXIST ?

Seems to be the next very natural query that presents itself to the mind.

If you read carefully the history of all the volcanic eruptions ; of all the great earthquakes that have laid to the ground the habitations of man, and buried the inhabitants under their ruins, you will find that premonitions have passed unheeded, because there were no inquiring, no scrutinizing minds to take note of them, and draw from them the proper inferences. In many instances sulphurous vapors have been seen arising from the ground; strange and mysterious underground noises are heard inspiring awe and terror alike in men and beasts ; mineral waters are seen to be altered ; soft waters are seen to become turbid in wells; the level of these waters is changed. Sometimes even the wells become perfectly dry, without any apparent reason. In caves, cellars, excavations, carbonic acid gas is noticed to emanate from the soil; magnets lose their power according to the force of the impending convulsion.

Experience has taught men to recognize in these phenomena, the symptoms of a mighty underground work—the signs of some terrible cataclysm near at hand—and are the same observed in the artificial volcano of Emery. Pliny, the Junior, in a letter to Tacitus describing the death of his uncle, ascribed it to suffocation, caused by the sulphurous vapors emanating from the ground, and calls them the forerunners of the catastrophe. It is well known that the sulphur mines are invariably found in close proximity to volcanoes—nay, in their very crater.

I have said that on the Continents none of the volcanoes are at a distance from the sea exceeding 75 miles in an air line. By some means or other the waters of the sea penetrate into the interior of the earth, since the vapors arising from the lava and the smoke coming out of the craters are the same as would result from the decomposition of salt water, and deposes large quantities of chloride of sodium. It is then that the salt water, coming in contact with the primary materials, causes the chemical decompositions and the generation of sulphurated hydrogen gas.

The sulphurets of potassium or sodium possess the property of decomposing the water at the mean temperature.

I will try to explain.

(To be continued.)

THE report of the surveyor employed to run the line of the proposed Canadian-Pacific Railroad has recently been published. The distances, as stated by him, are as follows : Montreal to Ottawa, 115 miles ; Ottawa to Mattawan, 195 miles ; Mattawan to Fort Garry, 985 miles ; Fort Garry to Yellow Head Pass, 985 miles ; thence to the limits of British Columbia, 52 miles, route by the Upper Fraser (British Columbia), by "short cut," 445 miles. Total length from Montreal to the Pacific, 2,777 miles. These distances are in large part estimated, as there has been as yet no survey of the whole route.

THE THEORY OF THE HOT BLAST.

By I. LOWTHIAN BELL.

From "Journal of the Iron and Steel Institute."

In the year 1828, J. B. Neilson patented an "improved application of air to produce heat in fires, forges, and furnaces, where bellows or other blowing apparatus are required." This discovery consisted, as is well known, in heating the air before it is propelled into the furnace; and although, from the title of the patent, Neilson and his colleagues appear to have expected to see it generally employed in all furnaces driven by compressed air, its use has, practically, been exclusively confined to those employed in smelting the ores of iron.

In 1834, Monsieur Dufrenoy was sent over to this country, by the Director-General of Mines of France, to report to the authorities at Paris on an invention, which at the time was truly described as one revolutionizing, in Scotland at all events, where it was first put into practice, the art of making iron.

This gentleman in a report gave good reasons apparently for this statement, by quoting the experience of the owners of Clyde Iron Works, which was as follows:—

For the year	1829	1831	1833
Temperature of blast....	Cold.	450° F.	612° F.
Coal used per ton of iron.	As coke.	As coke.	In raw state.
For fusion, cwt	133	86	40
" heating air, raw coal.	nil.	5	8
" blowing engines "	20	7	11
	153	98	59
Cwt. limestone per ton of iron...............	10½	9	7

From this it would appear that heating the air with 5 cwt. of coal had saved 47 cwt. of fuel in the furnace, and 8 cwt. similarly applied had been followed with an economy of 93 cwt., or above 69 per cent.

Besides this advantage, the make was increased by more than one-third, and a blowing engine, which only supplied three furnaces with cold blast, was equal to four when the air was heated.

The iron trade hesitated somewhat in crediting that the heat generated from 8 cwt. of fuel burnt outside the furnace, should be able to perform the duty of a very much larger weight burnt inside. Some writers on the metallurgy of iron, when speaking of the advantages of Neilson's system, have perhaps not been sufficiently careful in drawing a distinction between the saving directly due to its application and that arising in a collateral manner from its use. Looking at the question, however, in its commercial sense, the figures and language quoted from the work of Dufrenoy justified the character he gave to it.

There is undoubtedly, as this writer alleged, a saving, and, in the case of the Scotch furnaces, a very great saving of fuel by the use of the hot blast, exceeding considerably that of the weight of coal expended in the hot-air apparatus; but it seems a mere waste of time to endeavor to assign a cause, *in a heat-producing point of view*, why with the blast at 450 deg. F., obtained by burning 5 cwt. of coal, 93 cwt. of fuel should do the work of 153 cwt. with cold air, for the simple reason that it is incorrect so to state the economy effected by the invention. Thus, the burning of 7 cwt. instead of 20 cwt. of coal, per ton of iron, under the blast engine boilers, does not affect beneficially the quantity, nor the application, of the heat developed in the furnace itself.

Again, according to Dufrenoy, the coal used at the Clyde Works contains 64.4 per cent. of coke; but in the statements of the consumption he gives, there was used, per ton of metal, at the furnace blown with—

		Raw coal.
Cold blast	60 cwts. of coke, obtained from	133 cwt
Hot blast, 450°F.	38 " " " "	96 "
Difference....	22 " " Difference..	37 "

These quantities of coke, viz., 60 and 38 cwt., in reality only represent 93 and 58 cwt. respectively of raw coal, the difference between these numbers and those quoted above being waste of fixed carbon in the coking process. Hence, although it may be perfectly correct, commercially speaking, to say there is a gain of 37 cwt. of coal, in a heat-producing point of view, it is only 22 cwt. of coke we have to set against 5 cwt. of coal burnt in the hot-air stoves. This margin of 17 cwt. (the difference between 22 and 5 cwt.), however, is sufficiently remarkable, and various explanations have been given to account for the apparent anomaly. Some of these I propose to examine in the present section, and then to consider the question with the asssistance of the experiments and reasoning made use of in my own investigations on the action of the blast furnace.

The late Dr. W. Allen Miller* conceived the economy effected by the use of the hot blast to be due to the reduction of the ore taking place nearer the crucible, and thus concentrating the heat.

The analyses of the gases at different depths of the furnace, quoted in these pages, when blown with cold air, and with that varying fron 180 deg. C., to near 500 deg. C., do not appear to afford any countenance to the opinion advanced by this chemist.

Dr. Clark, Professor of Chemistry in Aberdeen, examined, in 1834, the action of the hot blast, and assigned as the cause of the saving of fuel that an ordinary furnace received 6 tons of cold air per hour, which he regarded as a tremendous refrigeratory passing through its hottest part, and thus repressing the temperature required for the complete and rapid reduction of the iron.

This explanation of the cooling effect of the air is true enough, but it scarcely accounts for the fact that one unit of heat in the blast was at that time saving something like four derived from the fuel burnt in the furnace. Dr. Clark, too, appears to have entertained the same opinion as that expressed some thirty years afterwards by Dr. Miller, viz., that the reduction of the iron was an operation performed in the hottest part of the furnace, whereas it would seem, from the analyses given in a previous part of this work, it is one almost exclusively effected in the coolest region.

Mr. Truran, in his work,† maintained that all writers previous to his time had greatly exaggerated the effects of the hot blast in the manufacture of iron. Dr. Percy‡ has effectually disposed of the chemical reasoning upon which this author supported his assertion. I am not aware that any one pretended that its introduction into Wales had been attended with the same beneficial results which distinguished its use in Scotland, and Mr. Truran certainly did not succeed in proving that Neilson had not, by his invention, afforded very valuable assistance in smelting the black band of that country.

Sir Wm. Fairbairn, in his work on the manufacture of iron, suggests the propriety of investigating the alleged consumption of fuel in the throat of the furnace, to which Mr. Truran attributed certain effects of the hot blast. Sir William himself seems to be under the impression that narrowing the throat increases the effect of the blast in this region. As no portion of the blast ever reaches beyond a few inches from the tuyeres in the form of atmospheric air, whether it is employed hot or cold, and whatever be the shape of the furnace, this view of a change in the nature of the combustion seems also devoid of any foundation.

Dr. Percy, who has examined with great care and minuteness the writings of almost every author, English and foreign, on this question, states* that, "after the positive, oft-repeated, and generally credited statements which have been put forth concerning the extraordinary effect of the hot blast in diminishing the consumption of fuel in the smelting of iron, it might seem superfluous to raise any question as to the fact."

The extraordinary effect alluded to by this author would appear to have more special reference to such savings as are contained in the published accounts of the late David Mushet, who gives 148 cwt., of coal coked for making a ton of iron with cold air, against 43½ cwt., used raw, with hot air, at the Clyde Works.

Dr. Percy considers that the abstraction of heat by the expansion of so much cold air when it enters the tuyeres must, by the mere act of dilatation, produce an unfavorable effect on the condition of the furnace, and that heated oxygen, combining more rapidly with incandescent carbon, willl give a temperature of greater intensity in the direct ratio of rapidity of combustion. This being so, he adopts, for the sake of argument, the supposition that a metal requir-

* "Elements of Chemistry."
† "Iron Manufactures of Great Britain," 1855.
‡ "Metallurgy of Iron and Steel."

* "Metallurgy of Iron and Steel," p. 418.

ing 1,000 deg. C. for its fusion, might be subjected to a temperature of 999 deg. C. for ever without melting. So it may be, the Doctor continues, in the blast furnace with respect to the carburization of the reduced iron, and certain other accompanying chemical actions, which may take place with slowness at one temperature, and with rapidity at another, slightly elevated. In order to produce these actions in a furnace on cold blast, it is requisite to consume a much larger quantity of coal than in a furnace on hot blast. A few degrees of temperature may make all the difference. As a further proof that it is *calorific intensity* which constitutes the superiority of the hot over the cold blast furnace, Dr. Percy mentions that in both cases the fuel is wholly consumed, and as the gas also which escapes from the furnace mouth has substantially the same composition, it follows that the *amount* of heat generated in a furnace working with cold blast is enormously greater for a given weight of pig iron than in one working with hot blast, the conditions with respect to quality of ore and fuel, dimensions of the furnace, etc., being supposed to be the same in both cases.

A word or two with regard to the absorption of heat by expansion as the blast enters the furnace, and the identity of the composition of gases from hot and cold blast furnaces.

Admitting that a current of cold air absorbs more heat by its expansion than one of hot air, both having the same pressure, will this absorption, whatever it may be, not be met by the addition of precisely the same quantity of heat if communicated to the blast itself? If so, we are not called upon to explain, so far as this item is concerned, any discrepancy between the heat communicated to the air, and the actual effect it produces in the furnace; for there would be no difference between the two. As regards the composition of the gases, it is difficult to determine, from mere reasoning, what this would be. The action of the blast on the fuel would undoubtedly, in both cases, give CO; and the actual quantity of CO_2 produced by reduction and carbon impregnation would be the same in the hot as in the cold blast furnaces, but what proportion of this CO_2 might suffer reduction to the state of CO is not so clear; but supposing it also were the same in both furnaces, inasmuch as the cold blast furnace is burning much more C to the condition of CO, and cannot convert more of this CO to CO_2 than happens when heated air is used, it follows that it is highly improbable that Dr. Percy's prediction as to their identity of composition would be realized.

Dufrenoy gives it as his opinion that the virtue of the hot blast is to be ascribed to the higher temperature of the furnace, and in support of this hypothesis, he adduces the fact that less limestone is used than when working with cold air, and hence "this diminution of the fluxing matter is the strongest proof that can be given of the temperature of the furnace. It proves that the earthy particles undergo a degree of heat powerful enough to fuse them, with the addition of a smaller quantity of flux."

This view of the condition of the zone of fusion is also that entertained by Dr. Percy, who reminds us that in looking into the tuyere of a cold blast furnace, the interior is black, instead of presenting the dazzling bright appearance of one blown with heated air.

As regards the diminution of limestone, there are other objects to be gained than the mere fluxing of the earthy constituents of the ironstone, such as the removal of sulphur, etc. This would appear to be so, because it often happens that the earths, in the proportions in which they exist naturally in an ore, constitute a readily fusible slag without the addition of any flux; thus, according to Colquhoun, in Scotch Black Band, we have them as follows:—

$$SiO_2\ 38,\ Al_2O_3\ 21,\ MgO\ 18,\ CaO\ 23 = 100.$$

Exp. 743. A mixture of these four substances in the specified quantities was exposed to the heat of a smith's forge, when it melted readily into a vitreous slag; and similarly, when they were in the proportions in which they are found associated in the Cleveland ironstone, they afforded a beautiful white glass.

The supposed duty of lime in removing sulphur, and it may be phosphorus to some slight extent, often leads to its use where the quantity, instead of adding to the fusibility of the slag, has a precisely opposite effect. Such, at least, is apparently the case in smelting the ironstone of Cleveland, judging from the slag formed upon one occasion, when, by way of experiment, all limestone was withdrawn from the charges. The slag was well fused, but the iron became hard, and contained above three times the usual content of sulphur.

The darkened appearance of the hearth, spoken of by Dr. Percy,* is susceptible of another explanation than that of an actual general refrigeration of this region. It is more probable, it occurs to me, that the cold air, meeting the slag and iron, chills a small portion of the fused matter as it passes the tuyeres; but this, of course, is not the action of air on carbon, but of air upon slag and metal. When, on the other hand, the melted contents of the furnace trickle down before a current of heated air, they also, no doubt, are chilled, but not to the extent to deprive them of fluidity before they pass beyond its influence; and, in this way, there is no accumulation of solidified matter, which gives rise to the prolonged tube or "nose," as it is termed, reaching far into the hearth.

To account for this supposed increase of intensity in the heat of a hot-blast furnace, Dr. Percy quotes the experiment of the Swedish metallurgist, Mr. Sandberg, who observed that heated oxygen combines more rapidly with incandescent carbon than cold oxygen, and that in consequence there "must be a proportionate increase of temperature, for, *cœteris paribus*, temperature will be in the direct ratio of rapidity of combustion."

Ordinary combustion of carbon is generally spoken of as an oxidizing of the carbon about to be burnt, and this no doubt, looking at the office played by oxygen in combustion generally, is a convenient mode of expressing the action. But as combustion of carbon is no more the oxidation of this element than it is the carburizing of oxygen, it will be more convenient, for our purpose, to speak of it in this inverted manner. Now, when oxygen is propelled into *a blast furnace*, it becomes rapidly carburized to its utmost limit of saturation, *i. e.*, it is speedily converted into CO. This union with carbon is so instantaneous that free O is never mentioned as the constituent of any analyses of furnace gases I have met with or made. Hence if there was any difference in the extent to which the oxygen became carburized as between cold and hot blast, it would manifest itself in the larger quantity of CO_2, where the rapidity of combustion was the least, because in this case the oxygen is unable to take up as much C as when the union is more speedy, and this slowness of combustion is what Dr. Percy concludes will happen when the oxygen is driven into the furnace as cold blast.

Were it consistent with observation that this carburization of oxygen were retarded by the want of heat in the oxygen, I would submit that the very opposite effect to that mentioned by this writer would ensue at the tuyeres, *i. e.*, instead of a cold blast furnace having a lower temperature generated in the hearth, it would be much hotter, inasmuch as the heat evolved by carburizing O to the lower state of CO_2 is three times that produced by the more perfect carburizing of the blast, which happens when CO is the product.

We need only refer to what has been said in Section XXX. on the origin of the heat in the blast furnace, to be satisfied that no temperature to which it would be possible to raise the air could compensate for such a difference as exists between carburizing O to the condition of CO_2 and CO, 8,000 calories being the product of one unit of carbon passing to CO_2 against 2,400 when the other oxide is produced.

The following analyses, given in Dr. Percy's work, show the volumes of CO and CO_2 per 100 volumes of the gases:—

Furnace.	Blast.	Gases collected at	CO.	CO_2.
Clerval	cold	Tymp	39.86	.93
Do.	190°C. (374° F.)	18 in. above tuyeres	41.59	.31
Eisenerz,	200° C. (392° F.)	Level of tuyeres	22.06	11 60

Is there, however, any valid ground for asserting that the carburizing of the injected oxygen is slower when it is cold than when hot? In the analysis, referred to by Dr. Percy himself, of the gas taken from the tymp (about the level of the tuyeres) of the Clerval furnace blown with cold air, there are 39.86 vols. CO to .93 vols. CO_2. At the same place, when the blast was used at 190 deg. C. (374 deg. F.), a specimen of gas 18 in. above the tuyere, and therefore vertically about as far from the point of entrance of the O as the other was horizontally, 41.59 vols. of CO were accompanied by .31 vols. of CO_2. This difference, small as it is, must be regard-

* "Metallurgy of Iron and Steel," p. 427.

ed rather as accidental than general, and under no circumstances can account for any great change in the actual temperature.

The information, however, elicited by an analysis of the Wear gases, taken from the level of the tuyeres, shows that carburization of the oxygen is not more rapid with the blast at 460 deg. C. (860 deg. F.) than it was at Clerval with cold air.

	CO	CO_2.
Experiment 744	37.5	.76
" 745	37.7	76
" 746	35 8	2.10
" 747	31.7	1.1
" 748	33.8	.8

All this argument, nevertheless, would have to give way to the fact, could it be established, that the temperature of the hearth of a hot-blast furnace really did exceed that of one blown with cold air.

I have already (Section XXXVI.) alluded to the difficulty experienced in obtaining, by means of the calorimeter, any data sufficiently uniform to enable me to determine the temperature of the contents of the hearth of a furnace. In the same place, however, I have given my reasons for believing that the cause of the difference between white iron and grey was simply one of temperature. This was done, it may be recollected, by heating white iron to a point known to be sufficient to produce grey iron, and the change was effected, *i.e.*, the white became converted to grey. The plan followed consisted in plunging a bar of white iron in a current of slag, as it issued from a furnace producing iron grey in quality.

Since writing the account of this experiment I have, by the kind assistance of my friends, the Messrs. Kitson, of the Monkbridge Works, at Leeds, satisfied myself of its correctness by another mode of procedure.

Exp. 749. About 60 lbs. of Clarence white pig iron was melted in one of their Siemens steel melting furnaces, and run into a mould of green sand forming a cube of 6 in. on a side. With the exception of a trace of white at one corner, the whole was converted into uniform good grey forge.

Exp. 750. The same quantity of the same iron as that used in the previous experiment was melted on a Saturday, and allowed to remain over the Sunday in the furnace, during which time it cooled slowly. The block, having a maximum diameter of 6 or 7 in., was entirely grey, chiefly No. 3, interspersed with some No. 4.

It seems, therefore, not unreasonable to accept the iron made in any particular furnace as a species of pyrometer for determining, if not the actual temperature of its interior, at all events of establishing a comparative test between it and that of another.

If, then, temperature is the governing cause of quality of iron (numbers), it is highly improbable that the same degree of heat intensity is, *cœteris paribus*, making white iron in one furnace and grey iron in another. It does seem more rational to suppose that if two furnaces are both running, say No. 3 iron from the same materials, one blown with hot air and the other with cold, they are making the same quality, because the temperature is the same in both.

This admission as to parity of temperature, of course, does not presuppose that the heat evolved by the combustion of carbon with hot air is not more intense than that arising from cold air; but what I affirm is, that, in consequence of the greater amount of iron and slag being melted with a given weight of fuel, when burnt with hot blast, the actual temperature in the crucible of such a furnace, is probably lowered to that of one blown with cold air having a smaller weight of material to use.

In recent years, by raising the temperature of the blast to 485 deg.C., the consumption of coke has been reduced to 28 cwt. per ton of iron when smelting Cleveland ironstone in a furnace 48 ft. high, and in which probably more than 60 cwt. (the quantity named in connection with the Scotch furnaces) would at least be required with cold air. Of the carbon in the 28 cwt. of coke mentioned above, after deducting that dissolved by the CO_2 of the flux, about 25 cwt. would be burnt to CO at the tuyeres.

25 cwts. C. × 2,400	= 60,000	calories.
Blast will contain about	16,000	"
	76,000	"

The intensity, however, of this quantity of heat has been shown in Section XXXVII. to be greatly augmented by that intercepted by the materials and brought down again to the zone of fusion.

This was in one case proved to amount

to 70 per cent. of that actually evolved by the quantity of fuel consumed to produce one ton of iron. So far as intensity therefore is concerned, we have to deal with

Units from coke per ton of Iron.......	76,000	calories.
Plus 70 per cent. intercepted and brought back..............................	53,200	"
	129,200	"

In like manner, with a consumption of 60 cwt. of coke, about 54 cwt. of carbon would be burnt at the tuyeres to CO.

54 cwt. C × 2,400 .... =	129,600	calories.
Plus heat in blast about	2,400	"
	132,000	
To which if we add for intercepted heat 70 per cent........	92.400	"
There is obtained...............	223,400	"

Now, it seems, on the face of it, incredible that the mere addition of 16,000 cwt. heat units, in the place of 2,400, should so alter the intensity of heat in the crucible as to make all the difference in the work performed.

Upon a former occasion* I called attention to the fact that whereas in the hearth of a blast furnace the C. was burnt to CO, in the hot-air stoves it left the fire-place as CO_2. This of itself would enable each unit of carbon to give 3.33 times as much heat when burnt in the hot air apparatus as when burnt in a blast furnace. The advantage, however, resulting from this change in the manner of combustion, would be considerably diminished by the great loss from radiation, and at the chimney of the heating stove. This is conclusively exhibited by the fact that whereas at least 4 cwt. of coal, equal to 32,000 cwt. heat units, are used per ton of iron in the stoves of a 48-feet furnace, only 16,000 find their way through the tuyeres.

Upon the same occasion I alluded to the circumstance that the mere alteration of the proportion of ironstone to coke conferred an advantage upon the hot-blast furnace, by presenting to the ascending gases a greater quantity of matter having a higher heat-absorbing power, ironstone being superior in this respect to coke.

Exp. 751. To determine the relative powers of coke, limestone, and ironstone, a cast-iron cylinder was provided, 4 ft. long and one ft. in diameter, closed at each end. The material to be operated on, broken as nearly as possible to the same size, was introduced into the cylinder, which it filled, and by means of an inch pipe hot air was introduced at the low end and allowed to escape at the upper. This was continued until a thermometer inserted at the top became stationary.

Numbers of a very constant character were obtained when using the same substance, and from these were deduced that bulk for bulk, taking coke as unity, the intercepting power of

Coke being..................................	1.00
Cleveland calcined ironstone was................	2.00
Limestone was..................................	1.60

These figures, however, indicate that the heat-absorbing power of a hot-blast burden is only about 10 per cent. superior to that of cold blast.

Under these circumstances, therefore, it is clear that neither modification of the circumstances just mentioned can account for more than a very small proportion of the actual saving effected by the use of heated air.

In the treatise by M. Dufrenoy, pointed allusion is made to a fact in connection with the use of hot air in France when using certain ores, from which it would appear that practically no saving whatever resulted from its application to the smelting of the mineral used at La Guerche* which, although containing only 42 per cent. of iron, gave a ton with 25 cwt. of fuel and cold air.

Mons. Dufrenoy dismisses, what seems to me a very important matter in connection with the theory of the hot blast, with the simple observation that the figures, in connection with the Guerche furnace he quotes, are "not favorable to the use of hot air," and I am not aware of their having attracted the notice of any subsequent writer on this interesting question.

It may be remarked that the "extraordinary saving" mentioned by most authorities as consequent upon the use of the hot blast seems to have been regarded in the light of one of general application.

* "Chemistry of the Blast Furnace. Transactions Chem. Soc. of London, 1869."

* This furnace was compared, by Dufrenoy, with a neighboring one at Torteron, using the same kind of fuel and ore, to which heated air was applied. The only change caused by the altered mode of working was, that the iron, instead of being white, as it was when cold air was used, became grey.

At all events, little stress has been paid to the well-known fact, that in many instances the economy of fuel was considerably less than in Scotland, where its much greater importance has, so far as is known, formed the usual ground upon which its powers were considered.

Dufrenoy himself, for example, mentions the circumstance that at the Plymouth Iron Works, near Merthyr Tydvil, a ton of iron was produced with 53 cwt. of raw coal, and that by the use of hot air it could be reduced to 36 cwt. The saving, 17 cwt. of Plymouth coal, only represents 13 cwt. of coke, instead of the 22 given as that effected in Scotland by hot air.

Now, the problem I would suggest to those who allege that "calorific intensity in what may be considered the most active part of the furnace is higher in the case of hot blast than in the case of cold blast" is, whence arises it that the addition to this assumed intensity of heat in the crucible is attended with such different results as those just mentioned?

I cannot help thinking that the answer to the above inquiry is to be sought for in an entirely different direction, and, in pursuit of which, may be quoted the results of certain experiments described in the earlier sections of this work. In these it was conclusively proved that differently prepared specimens of oxide of iron and different kinds of ore, all being peroxides, were very differently affected by the application of heated CO. Thus, in about 7 hours, at a temperature of 410 deg. C. (770 deg. F.), in

		Per cent. of its original O.
Exp. 30.	Fe_2O_3 from calcined nitrate, lost.	72.7
" 29.	" precipitated........ ..	66.7
" 28.	" from calcined $FeSO_4$	61 7
" 35.	Lancashire hematite..............	57.4
" 34.	Calcined spathos ore	28.4
" 33.	" Cleveland ore	20.7
" 26.	" " "	9.4

Now, the two experiments 33 and 34 may be taken almost as an exact type of what happens in the Plymouth and Scotch furnaces respectively. We have calcined spathose ore losing its oxygen with nearly one-half more rapidity than that of the Cleveland hills. This would mean that for the purpose of complete reduction we should have to expose the last-mentioned mineral for a one-half longer period of time than the other.

Let us see how this difference in susceptibility to reduction accounts for the greater consumption of fuel in the case of the black band, as compared with the ore smelted at the Plymouth Works, both of which will be regarded as yielding the same percentage of iron.

In the first place, it is obvious that it cannot be from any difference in the cooling effect of expanding air, as the blast is cold in both cases; neither can it be rapidity of combustion causing intensity of heat, because, if both furnaces burnt the same quantity of fuel in a given time, the Scotch ore would still continue to require the larger quantity of combustible per ton of iron.

It can hardly be alleged that the same quantity of iron and slag to be melted, derived from black band, can require for their fusion in the hearth one-half more heat than do the same substances from the mineral operated upon in South Wales.

Instead of all this, let us suppose that in the hearth of a blast furnace a certain mixture of reduced iron and earthy matter had to be fused, with the minimum quantity of fuel capable of evolving, with cold air, the necessary heat. From the combustion is generated a certain quantity of CO, which we will further suppose to be able to carry off all the oxygen contained in the minerals, without difficulty. This carbonic oxide now commences to flow through the oxide of iron at a rate determined by the rapidity of the combustion and fusion at the tuyeres.

Reduction is effected by the current of CO, and in the case of the Plymouth mineral it takes place at such a rate that by the time about 40 cwt. of coked fuel, the produce of 53 cwt. of Welsh coal, are burnt at the tuyeres, deoxidation has been completed, and carbon-impregnated iron is ready for fusion.

If, however, another ore, say black band, parts with its oxygen much more slowly than that just described, it is certain that the exposure to the reducing agent must, by so much, be prolonged. This, however, cannot be accomplished if the rate of fusion continues the same as was in the Welsh furnace. There is, therefore, no alternative, in a small furnace, but to retard fusion by the addition of fuel. This reduces the weight of material to be melted, and at the same time supplies an *extra* quantity of CO, which also assists in overcoming the want of susceptibility of reduction inherent in the more refractory ore.

The law, therefore, which I believe determines the whole question of differences of fuel required to smelt ores of different kinds, but containing the same percentage of metal, and which constitutes the value of the hot blast, is—*that the rate of reduction must not proceed less rapidly than that of fusion.*

It must not be imagined, if a sample of the Scotch black band and one from Plymouth were exposed to a current of heated CO, that deoxidation would necessarily take place exactly at the rates indicated by the quantity of coke required respectively to smelt them; at the same time a fair idea would in all probability be obtained by the information afforded by such a trial.

In the hearth of the Scotch furnace there will be evolved for each ton of iron something like 132,000 cwt. heat units, against 88,000 at Plymouth, both being blown with cold air. It will be observed that in both cases the actual quantity of heat is greatly in excess of what can be possibly required for fusion of iron and slag. This excess, after satisfying the requirements of the crucible, is carried off in the gases, a much larger quantity, of course, in that where the consumption of fuel per ton of iron is the largest. The application of the law just laid down to the two examples now considered, consists in supposing that under the circumstances of size of furnace, etc., whereas 60 cwt. of coke was needed in Scotland to bring the reducing and fusing powers in harmony with each other, the coke from 53 cwt. of raw coal (about 40 cwt.) sufficed to effect the same object at Plymouth.

It may not be altogether out of place, before proceeding further with the present argument, to examine a little in detail the performance of the Guerche furnace, which, although of very small dimensions, when using ore of about the same richness as that of Cleveland, and requiring the same quantity of limestone, produced with cold air, a ton of metal for 24.92 cwt. of fuel.

This of course means that, notwithstanding the small capacity, the ore employed surrendered its oxygen so freely that the current of gases proceeding from the above-named quantity of fuel, became saturated with oxygen by the time they reached the throat, and quite as rapidly as the carbon burnt at the tuyeres could fuse the reduced metal and slag.

No account is handed down to us of the composition of these gases; indeed, at the period of M. Dufrenoy's observations, this subject had received but small attention. All we can, therefore, do is to consider how far the quantity of fuel consumed can be made to correspond with the actual amount of heat required.

The fuel employed consisted of two-thirds charcoal and one-third coke, but as the work done at Guerche was compared with that of another furnace (Torteron), also using the same mixture of combustible, but blown with hot air, and as we are now considering the quantity of heat, which is the same practically from coke and charcoal, the presence of the latter may be disregarded.

Fuel consumed per ton of iron	24.92 cwt.		
Ore	48.74		
Limestone	11.16		
Estimate of heat development—			
Fuel burnt	24.92		
Deduct, say 10 per cent. for impurity	2.49		
	22.43		
C in limestone carrying off equal weight from fuel ($CO_2 + C = 2CO$)	1.32		
			Units.
C burnt to CO	21.11	× 2,400 =	50,664
C of this CO burnt to CO_2, say	6.00	× 5,600 =	33,600
Heat units in blast from compression, say			2,000
			96,264

Heat absorption as per table in Section XXVIII.

Evaporation of H_2O in fuel	312	
Reduction of Fe and carbon impregnation	34,548	
Expulsion of CO_2 from limestone 11.16 × 370	4,129	
Decomposition of this CO_2 1.32×3,200	4,224	
Do. H_2O in blast	2,720	
P, S, and Si reduced, assumed one half*	2,087	
Fusion of iron and slag	23,100	
Transmission of heat through sides	3,658	
Tuyere water	nil.	
	74,778	
Leaving (which is more than ample for escaping gases)†	11,486	
		96,264

Thus it will be observed that even with cold air, under favorable conditions, a ton of iron can be obtained from an ore of only medium richness with 25 cwt. of fuel.

* Probably less P and Si than in Cleveland iron.

† In all probability, 6 of C, burnt to CO_2, is 1 cwt. in excess of actual quantity, which would reduce heat in gases to 5,886 units.

(*To be continued.*)

REPORTS OF ENGINEERS' SOCIETIES.

INSTITUTION OF CIVIL ENGINEERS (LONDON).—March 5, Thomas Hawksley, Esq., President, in the chair. The paper read was "On the Kind-Chaudron System of Sinking Shafts through Water-Bearing Strata, without the use of Pumping Machinery," by Mr. Emerson Bainbridge, Assoc. Inst. C. E.

Of the total expenditure necessary to open out a coal-field, one of the chief items of cost was caused by the heavy expenses incurred in sinking the shafts, and when such sinking happened to pass through water-bearing strata, the proportion due to this head, of the total cost, was much increased. When a shaft exceeded 200 or 300 yards in depth, and when the water occurred near the surface, it was usual to keep the water back by the insertion of cylindrical metal "tubbing," placed upon a hard bed of rock at a point immediately below the lowest feeder. Where pits were less than 100 or 200 yards in depth the application of tubbing was not of much service, as the movement and dislocation of the strata, consequent upon the removal of the coal, generally caused the water to find its way into the underground workings. The sinkings in which there was the largest quantity of water had been carried in Belgium through the chalk, and in England through the Permian series; these rocks usually being sufficiently porous to contain large volumes of water. Without exception, in England all such sinkings had been made by the use of pumping machinery of sufficient power to keep the pit, during the process of sinking, comparatively dry.

It was stated that the question of dealing with wet sinkings in the most economical manner would, before long, become of much greater importance than heretofore. In the report of the Royal Coal Commission an estimate was given of the coal remaining in the British Islands, as follows:—Coals yet remaining which is or will have to be reached by sinkings through the coal measures, 90,527 million tons; coal yet remaining which is or will have to be got by sinking through the Permian and other formations overlying the coal measures, 104,418 million tons; total, 194,945 million tons.

It thus appeared that 104,418 millions of tons, or 54 per cent. of the remaining resources of the British coal-fields, would have to be reached by pits sunk through the Permian and other formations more recent thon the coal measures; and, as a rule, more likely to be saturated with large volumes of water. With such important evidence bearing on the future of coal-mining, it had been considered that the present was an opportune moment to bring under the notice of the Institution a description of a mode of sinking shafts through water-bearing rocks which had proved successful in many cases on the Continent.

The plan of sinking pits hitherto practised in this country consisted in dealing with the water by means of large pumping engines, in leaving the bottoms of the pits dry enough to allow the sinkers to block the well, and in keeping back the water in the upper strata by metal rings, cast in segments about 4 ft. long, and connected by wooden joints, which were wedged tight, when all the tubbing was fixed. The evils of this system were:—(1) The heavy first cost of the plant, when special pumping machinery was used. (2) The expense of the wedging tubs, and the cost of fixing them. (3) They delay caused by the sinkers being compelled to work always in water. (4) The high first cost of the tubbing and of fixing it in the shaft, and the liability of the tubbing leaking in consequence of the numerous joints.

In the application of the Kind-Chaudron system these evils were to a great extent avoided. The system consisted of a combination of Mr. Kind's well known apparatus for boring wells, with an ingenious device, invented by M. Chaudron, for fixing cylindrical tubbing under water in such a manner as to make it quite secure and water-tight. In the latter part of 1871, the author, accompanied by Mr. W. Cochrane, visited the Maurage pits, near Mons, where two shafts were being sunk by this process. These shafts, though having a depth respectively of 373 ft. and 593 ft. at the date of that visit, had been bored that depth under water with a diameter of 13 ft. 6 in., the water having been constantly standing at a depth of 37 ft. from the surface. The Chaudron system consisted of the following distinct processes:—(1) The erection of the machinery on the surface. (2) The boring of the pits to the lowest part of the water-bearing strata. (3) The placing of the tubbing. (4) The introduction of cement behind the tubbing to complete its solidity. (5) The extraction of the water from the pits, aud the erection of wedged cribs to secure the moss-box. The machinery on the surface consisted of a capstan engine, which raised the debris from the pits, and a vertical engine, by means of which the boring tools were lifted at each stroke, the speed of the latter engine varying from 15 to 18 strokes per minute. The first tool applied was the small trepan, which weighed 8 tons and bored a hole 4 ft. 8¾ in. in diameter, the depth of the boring being increased at the rate of from 6 ft. to 10 ft. per day. The pit was enlarged by a trepan weighing 16½ tons, which increased the size to 13 ft. 6 in., and was kept from 10 to 30 yards behind the pit made by the smaller trepan. The larger boring tool had 28 teeth and the smaller tool 14 teeth, each tooth weighing 72 lbs. The boring by the larger trepan did not progress faster than about 3 ft. per day of 24 hours. The boring was generally carried on during the day, the remaining 12 hours being employed in raising the debris from the pits. When the bottom of the water-bearing strata was reached, the tubbing, which consisted of metal cylinders cast in complete rings of an internal diameter of 12 ft. and a length of 4 ft. 9 in., was placed in the shaft, the rings of tubbing being connected by bolts. The tubbing was tested by hydraulic apparatus to ⅓ more pressure than it was expected to be subjected to. The rings of tubbing were let down into the shafts by means of the capstan; the moss-box at the bottom of the tubbing being placed in the pit first. The moss-box consisted of two cylinders, one sliding inside the other, and each having a flange broad enough to form a chamber to hold a quantity of ordinary moss. When the moss-box reached the bed which was prepared for it at the bottom of the pit, the weight of the superincumbent tubbing pressed upon the moss, and formed a water-tight barrier. The tubbing being thus fixed, the annular space between it and the sides of the shaft was filled with cement, thus insuring the solidity of the tubbing; after this was finished the standing water in the shaft was drawn out, and the joint below the moss-box was made permanently safe by the fixing of several rings of tubbing resting on 2 strong wedging cribs.

The comparative cost of sinking by the processes referred to was shown by two tables, one of which exhibited the complete cost of sinking, and the time occupied by the ordinary system, at 18 different collieries, whilst the other gave the same information for 10 collieries put down by M. Chaudron's process. The results showed that, whilst, with the system of sinking by the aid of pumping machinery, the average cost per foot had amounted to £114.7, and the rate of sinking to 8.9 ft. per month, with the Chaudron process the average cost of all the pits was equal to £22.9 per foot, and the speed of sinking to 15.8 ft. per month. This striking result, which was so much in favor of the Chaudron system, evinced the importance which this mode of dealing with water-bearing strata was likely to have.

It was remarked that, where a large quantity of water occurred in shallow sinkings, tubbing would be of no avail, and the economy of boring by the "Niveau plein" system would probably be considerable. On the other hand, where the strata were hard, and where the feeders of water were so well separated by beds of rock as to allow them to be dealt with separately, the ordinary system of sinking might prove as economical as the Chaudron process. The boring of the shaft by the Chaudron process could not be said to be advisable below the water-bearing strata, as with an increased depth the time which could be utilized in boring would become less, and further, the small particles into which the rock was broken by the tool hindered the sinking, so that it progressed more slowly than when the shafts were sunk by the ordinary mode.

March 12th.—The paper read was "On the Soonkesala Canal of the Madras Irrigation and Canal Company," by Mr. J. H. Latham, M. Inst. C.E.

The object of this communication was to give a general description of the canal between Soonkesala and Cuddapah, recently constructed for irrigation and navigation by the Madras Irrigation and Canal Company; and to direct particular attention to the mode of safely constructing high banks for canals or tanks, illustrated by that work.

King's College Engineering Society.—At a general meeting of this Society, held February 23d, Mr. Hunter, President, in the chair, Mr. Baynes read a paper on "Submarine Works." The author began by describing the different methods for laying sea foundations, viz., by piles, either in double or single rows; by caissons; and by rubble masonry of huge blocks, or by masonry laid by divers or diving bells, describing the different machines used. In conclusion, he gave an account of the submarine boats that had at different times been invented, showing the causes which prevented their use, the principle one being the want of view.

IRON AND STEEL NOTES.

Homogeneous Cast-Steel at one Operation.—The novelty which constitutes the invention of Mr. L. Viger, of Montreal, Canada, is the use of the admixture in predetermined and definite proportions of pulverized plumbago, anthracite, charcoal, bituminous coal, coked or in the natural state, compressed or not, with pulverized iron ores, oxides, or carbonate of iron, iron-sand, or wrought-iron, iron scraps, shavings, clips, and sponge, and metallic iron of any description, in a crucible or reverberatory furnace, or re-heating or puddling or air-furnace, or with what is known as a Siemens furnace, or in any other furnace heated by gas, to make cast-steel of any desired quality in one operation. The mixture, if used in a furnace, to be covered or not with a flux of glass or blast-furnace cinders, or with glass-making materials, slabs of soapstone, tiles, bricks, or any other covering, and if the ore or carbon used contains earthy matter, the slag scoriæ which they will furnish may render other coverings unnecessary. In a furnace heated by gas if a neutral flame, neither oxidizing nor carburizing, can be produced, no covering is required. The above admixture to be used in the following proportions—from two-tenths of 1 per cent. to 30 per cent., and even 40 per cent. of said carbon in weight of the ore used, or of the oxide of iron, or carbonate of iron, according to the purity of the oxide or carbonate of iron, and of the carbon used, and according to the quality of the cast-steel to be produced. The above admixture, either loose or compressed, with a coating of plumbago or other carbonaceous matters, and covered or not with the above-mentioned coverings. To the admixture may be added a small quantity of oxide of manganese, lime and fluate of lime, in equal proportions, wood, tar, or common glue may be added in compressing. To insure uniformity, the ores and carbons used should be free from all impurities, finely pulverized, thoroughly and uniformly mixed, and when weighed must be dry, and sufficient carbon added to insure the carburizing of the ores to the required degree.

American Pig Metal for Bessemer Steel.—Prof. A. A. Fesquet contributes the following article upon this subject to the "United States Railroad and Mining Register:"

"If we examine the history of the Bessemer process in America, we will see that it has passed, and is still passing, through the same stages and difficulties it had to encounter in England.

"In that country, the first attempts made with ordinary kinds of pig-iron, resulted in irregular working, and in a steel of inferior quality. The first successful results were obtained from imported Swedish metal, high in price, and the supply of which was insufficient. Later, when the requisites of a suitable pig-iron were better known, when the various British metals were analyzed and tried, and especially after the great development of the iron manufacture in the Cumberland district, then only was the success of the Bessemer process entirely esablished in England.

"We might have profited by the experience of the English ironmasters, and availed ourselves of the knowledge they had gained as to the metals to be used; but it would appear that the American steel-maker considered that it was the *process*, the "Bessemer process," which was all that was essential for successful results. Therefore, Bessemer steel works have been erected in various localities of this country, at great cost and perfect in construction, but, to say the least, with indifferent success, for the reason, as we believe, that the proper metal has not been employed.

" The real success of the Bessemer process in this country will date from the time when the purest kinds of American ores shall be smelted in blast furnaces, working for Bessemer pig only. Then will the steel manufacturer be certain of a sufficient supply constant in quality, and the treatment of which will not bewilder the operatives.

" A personal examination of many samples of iron ores from North Carolina, and the analyses recently made by Dr. Genth of similar ores from the same State, convince us that they are singularly well adapted to the manufacture of Bessemer and tool steel, and also of Swedish iron. We base this belief upon facts derived from the composition of the best known qualities of pig metal used abroad for the Bessemer process, and from that of the ores employed.

" The following analyses are of Bessemer pig metal, made at:

I. Cleator (Cumberland district, red hematite).

II. Harrington (Cumberland district, red hematite).

III. Workington (Cumberland district, red hematite).

IV. From English hematite mixed with Titanium ores from Norway. This pig is said to answer well for the Bessemer process.

V. Askam, Furness Iron and Steel Company (red hematite).

VI. Fagersta (Sweden—Magnetite).

VII. Neuberg (Styria—Spathic ores).

	I.	II.	III.	IV.
Metallic iron	93 552	93.100	92.850	93.47
Graphitic carbon.	3 082	2.952	2.997 }	3.31
Combined Carbon	1.265	1.235	1.134 }	
Silicum	1.389	2 286	2 706	1.86
Sulphur	0.068	0.075	0.068	0.071
Phosphorus.....	0.027	0.055	0.028	0.076
Manganese	0.216	.288	0.140	0.50
Titanium.... ...	6	6	0.007	1.15
	99.605	99.997	99.930	100.437

	V.	VI.	VII.
Metallic iron	93 191	......	90 507
Graphitic carbon	3.928	3.527	3 180
Combined carbon...........	0 109	1 012	0 750
Silicum	2.640	0.854	1 960
Sulphur.....	0.004	0 010	0.018
Phosphorus	0.014	0 031	0.040
Manganese	0.093	1.919	3.460
Copper....................	......	......	0 085
	99.979	......	100.000

"All these samples show that the proportion of graphite carbon largely predominates over that of the combined. Direct experiment in the converter has proved the necessity of such an excess of graphite, since pig metal with a large percentage of combined carbon, and good for puddling, did not give satisfactory results in the Bessemer process. As the per cent. and nature of the carbon in pig iron are especially due to the ratio between the fuel and the burden, they depend more on the mode of working the stack than on the nature of the ores, although some persons assert that the metal from silicious ores is more readily permeated with graphite.

" The proportion of silicium is also uncommonly large, and the knowledge of its effeets is of comparatively recent date. Like carbon, it acts as fuel for supporting the heat during the blast; it makes the charge work hot. This is its only advantage, because, although the greater part of the silicium is oxidized at the begining of the blast, and even before the carbon, there still remains a small proportion of it, sufficient to render the metal hot short, and requiring the addition of spiegeleisen to be entirely eliminated.

This red-shortness of metals made from silicious materials, and free from sulphur, has already been ascertained several times. Cumberland pig, puddled alone, gives a red-short iron. Cast steel, rich in silicium, is also red-short. We have ourselves noticed similar results, in connection with the presence of a slight proportion of iron oxide, in experiments made with the Martin process, when all red-shortness disappeared after the addition of spiegeleisen, or Franklinite, which would not be the case should the metal be sulphurous. Moreover, Mr. Caron has already observed that, under the influence of a high and oxidizing heat, manganese aids in the transformation of the silicium into silica.

" The effect of spiegleisen is thus manifold. It restitutes to the decarburized metal the desired proportion of carbon; it cleanses it from oxides and thick slags, its manganese taking the place of iron and forming very fluid slags; and, lastly, it removes all the silicium.

" We need not dwell on the pernicious effects of sulphur and phosphorus; they are too well known. Although these substances are found in all of the samples of Bessemer pig metal indicated, and which are of superior quality, their proportion is so small as to amount practically to nothing. Nevertheless, in ores, sulphur is the less objectionable of the two, since, by careful roasting, it may be nearly entirely removed. In Styria, for instance, 4 per cent. of sulphur in the ores is not considered a bar to their employment.

" Manganese, found in variablé proportions in the above named pig metals, is a valuable substance, so much so that spiegeleisen may be dispensed with in the treatment of certain pigs rich in manganese.

" To sum up, we may say that, provided the ores are practically free from phosphorus and sulphur, they are suitable for the manufacture of Bessemer pig; and such is the case with the iron ores of North Carolina referred to, which have the additional important merit of containing a notable percentage of manganese and chromium.

" Red hematites are not, as some people state, the best or only ores for the manufacture of Bessemer pig. It should be remembered that the Bessemer process was first rendered a success in England through the use of Swedish pig made from magnetic ores, and that, at the present time, Sweden is still ahead in regard to the quality of its Bessemer steel. The development of the red hematites of Cumberland made a cheaper metal—good, indeed, but not better than the Swedish one. The great advantage for England was a home product, of which a large supply could be had at a reasonable price.

"Next after Sweden, in the quality of its products, comes Styria, with its metal from spathic ores. At the same time, we do not wish to convey the idea that *pure* red hematites are inferior to *pure* magnetic or spathic ores. We believe that the superiority of the Swedish or Styrian products is due to a greater care in the roasting process, and to the purity of their fluxes and fuel (charcoal).

"The ores which we have examined as coming from North Carolina are of the primary kinds—that is, principally magnetites and compacted hematites. In places, as in Sweden, they become mixed, the hematites running into magnetites, and conversely.

"The magnetites are either pure or mixed with titanic acid. All the pure magnetites which we have examined are sufficiently rich for the blast furnace, yielding from 40 to 50 per cent. and over of metal. Should it be desirable to enrich them further for the bloomery fires, this may easily be done by means of magnetic machines, for, unlike many of the magnetic ores of Northern New York, the grains of quartz do not strongly adhere to the magnetic portions, and are completely separated by the crushing process. Many kinds of the titaniferous magnetites may be treated in the same manner, and titanic acid left behind. Some of the pure magnetites examined contain manganese, aud they are remarkably free from sulphur and phosphorus.

"The titaniferous magnetites are especially worthy of consideration. They are said to exist in great abundance, and are free from sulphur and phosphorus; they produce the most excellent quality of tool steel, and average 55 per cent. of metal, from 10 to 12 per cent. of titanic acid and from 1 to 2 per cent. of manganese and chromium. They are superior to all other kinds of ores for the lining of puddling furnaces. They will, mixed in proper proportion with other ores, and with suitable fluxes, greatly increase the quality and toughness of the metal. The fluxes to be preferred for such ores are the multiple silicates holding metallic bases, and these are abundantly found in the immediate vicinity. We have personally examined metals cast directly from titaniferous ores, without admixture of other ores; and there are analyses of slags from Swedish blast furnaces holding about 10 per cent of titanic acid. Several of the samples of Bessemer pig above given show the presence of titanium; one especially, where the proportion is quite large. The per cent. of titanic acid in the ore must have been considerable, since it is well known that the greater part of that substance goes into the slags.

"The compact red hematites of this part of North Carolina are also remarkable for their purity, abundance, and considerable yield of metal. They are silicious, like the Cumberland hematites. This is an advantage for the manufacture of Bessemer pig, which requires silicium; but should these ores be desired for other purposes, the excess of free silica may be neutralized with aluminous magnetites, also found in the vicinity.

"Spathic ores, crystallized or compact, have been found, but their development has not yet been sufficient to determine their extent.

"The fluxes necessary to the smelting of all these varieties of ores are said to be abundant. They are, granular limestone, clays, ochres, garnets, and the gangues of the ores themselves.

"Charcoal is abundant in the immediate vicinity of the ores, and will be so for many years to come. Moreover, the important coal fields of the Dan and Deep rivers are there to supply any deficiency in vegetable fuel.

"On pig metal manufactured from iron ores such as we have described, in whatever locality they may be found, depends, in our belief, the profitable success of the steel and of the first class bar iron manufacture in this country."

RAILWAY NOTES.

Railways in Turkey.—The Government is making strenuous exertions to extend the lines of road. Important works are in operation to unite Constantinople with the capitals in Western Europe. There is also a very important project to connect Scutari with a network of roads in Asiatic Turkey, ultimately destined to unite India and Europe. The first section from Scutari to Ismid (the ancient Nicomedia), 90 kilometres long, will be open for traffic in September next. The extension to Eski-Schehir, 200 kilometres further, is surveyed, and a provision made for a capital for its construction.

Performance of a Locomotive.—The following extract from a latter, detailing the performance of one of Baird & Co.'s locomotives, will be read with interest.

"Engine 422 has been taken into the shop for repairs, and as her performance has been an extraordinary one, you will, I am sure, desire to know some of the particulars of her career thus far.

"She was placed on the road on the 17th day of October, 1867, and ran until the 14th day of May, 1871. During the whole of this time she hauled fast and heavy passenger trains over Middle Division, and made the wonderful run of 153,280 miles, losing only 3 trips, which was during November, 1869, to have 6 new flues put in and to clean the mud out of the waist of the boiler. She also lost 6 round trips in May, 1870, getting a larger tank, to enable her to make the run from Altoona to Harrisburg (132 miles) without a stop.

"This, however, was no fault of the engine and should not be counted against her.

"As an offset against the nine trips lost, she made 11½ extra trips between Altoona and Harrisburg.

"The total cost for repairs up to the time she was laid off amounted to $3,727.06, or 2.44 cents per mile. Our book account makes these amounts somewhat greater, but I have deducted all items not actually running repairs, such as the new tender, cost of applying air brakes, etc., which, although under our system of accounts are necessarily charged to repairs, actually do not belong there.

"When Engine 422 was taken into the shop, she was reported as run down in the working parts, but uniformly so; all the bearing surfaces being smooth and good and her general condition being better than is usual with engines taken in for repairs. The cost of placing her in thorough repair is estimated at $1,262.73."

ENGINEERING STRCTURES.

The Draw-Span of the Davenport Bridge.—The great draw-span of the new bridge over the Mississippi at this point was circled or turned for the first time at noon yesterday. It is the longest drawbridge on the Mississippi, and the heaviest in America, if not in the world. Yet ten men pulled it round quite easily, with the aid of a single pulley, heavily loaded with lumber from end to end though it was. Such of our readers as have not had an opportunity of examining this great work will be interested in a description conveying an idea of its tremendous strength. The draw-span as it stands is a Whipple truss inverted; that is to say that its top chord is in tension and its bottom chord is in compression, which is exactly the reverse of the style of the fixed spans of the bridge. The whole strain of the draw-truss is carried right to the centre from the ends, while in the fixed spans the strain is transmitted from the bottom of the posts up to the tie-bars to the ends, throwing the top chord into compression. The draw is, in exact figures, 366 ft. and one quarter of an inch in length and the posts 46 in number. The posts, to be particular, are connected by top and bottom chords, top and bottom struts and diagonal lateral bracing. The weight of the iron in the span, exclusive of the turn-table, is 871,784 lbs., or about 426 tons.

The turn-table is a new invention of C. Shaler Smith, President and Chief Engineer of the Baltimore Bridge Company, and this is its first application. It differs materially from any other work of the kind. In describing it, we will commence with the bed-circle itself, resting on the centre or pivot pier. The circle is 32 ft. in diameter, and is composed of six segments, each 8 in. deep by 12 in. wide, and weighing 6 tons—36 tons for the circle The top surface is bevelled, the inner side of the surface being highest. On this bed-circle are mounted 36 heavy cast-iron wheels, 2 ft. 6 in. in diameter, with a 12-in. face; through the centre of each wheel is placed an adjustable tie-rod, which runs to the centre-pin as a radial bar; the wheels are also spaced at correct relative distances by an inner and outer set of distance-plates, which, with the radial rods, regulate the distance and travel of each wheel in the circle. The wheels are cast, turned and faced up to a bevel exactly corresponding to the bevel surface of the lower bed castings, but placed with their greatest diameter on the outer side of the bed-circle, thus giving to each wheel an enlarged circumference to travel on the increased circumference of the outer side of the bed-circle over the circumference of the inner side. Thus each wheel, from its formation and the formation of the bed on which it moves, naturally tends to travel in a segment of the circle, and by avoiding the tendency which square-faced wheels have to travel in right lines or on a tangent, escapes any severe tension on the centre of the radial rods, consequently avoids the severe friction which would otherwise be inevitable. On the wheels above described is mounted a rotary table, formed in six segments, averaging 5 tons each, and 5 ft. in depth, which are accurately fitted together at their joints, and secured by heavy keys and bolts, forming a circle as correct and solid as though cast in one immense piece.

On the exact radial centre of the masonry is mounted a huge centre-pin bearing, 2 ft. 8 in. high, with a base 4 ft. in diameter. Across the top of this and bolted into the inner surface of the rotary table are two cast struts or cross beams of immense weight (averaging 6 tons each) and great strength, which render the office of transmitting to the centre-pin bearing and the rotary bed their correct relative proportions of the pondrous weight brought upon this strut by the main centre post of the superstructure, the main posts being mounted upon heavy cast-iron shoes seated upon the main girder. Besides this girder or strut, crossing the centre-pin and taking eold of the rotary table, there also radiate from the centre-pin bearing and from the centre of the main girder numerous struts and tension-rods of wrought iron, which serve the purpose of keeping at all times the rotary bed in correct tram or perfect circle from the fixed centre. The exact weight of this turn-table, exclusive of the power spoken of below, is 205,416 lbs.—almost 103 tons.

The rotary power which is to turn this great drawbridge has rather a novel method of application, as any one can see.

Immediately over the centre portal arch will be placed a reservoir of wrought iron, to contain about 3 barrels of pure glycerine, which will flow down through tubing into 4 hydraulic pumps which will be worked by a steam engine placed on a level with the railroad fleck and will be forced by the pumps into two huge "rams" or "jacks" placed on each side of the span at the centre posts. From the plunger of each "jack" will be led a wire cable $1\frac{1}{2}$ in. in diameter, so arranged that as the plunger of the "ram" on one side of the span is ascending and shortening the cable lead on his side, the other "ram" will be descending and passing out or lengthening his cable —and as one "jack" shortens the cable attached to it, he draws himself, and consequently the side of the span, toward the point where the other end of his cable is permanently made fast in the solid masonry of the pivot pier; and at the same time the other "ram" passing out or giving line on his side of the truss permits the span to rotate in accordance with the pull of the other "ram," and is prepared at a moment's notice to act as a brake, and entirely check the span, or to cause it to turn in an opposite direction.

Either "jack" can pull, and either one can hold back, as the supply and discharge of pipes at the top and bottom of each "jack" are arranged with a view to make them act as reciprocators.

No fluid is lost by working, further than by leakages at joints and valves; while the hydraulic pumps are intended to be worked by steam power, they are also arranged for being worked by "hand power," in case of necessity.

The rotary power of this draw has been designed with especial view to perfect simplicity and durability, and avoidance of use of gearing of any kind; nor is there anything new or scientific in the plans adopted.—*Exchange.*

Detroit River Tunnel.—Work on the (Detroit side) shaft began Dec. 1, 1871, and was finished Jan. 31, of this year, when the bed rock was reached, 108 ft. below the surface of the river: depth of masonry, 114 ft; upper 89 ft., is 15 ft. diameter and 16 in. thick, the remaining 25 ft. has diameter of 9 ft. with 12 in. walls. The drainage tunnel starts from bottom of shaft, 8 ft. above rock, leaving well below for water that may come into shaft. Drainage drift excavated under river to point 130 ft. from shaft, a daily average of 5 ft., through very hard clay, having layer of boulders, from a few ft. to a cubic yard in size, half way up in drift. Latterly these are smaller and less frequent, and it is thought will either run out or dip below bottom of drift. Portions of tunnel have stood well a week unsupported, but tunnel is carefully lined with masonry within a day or two —an 8 in. circle of the hardest brick, every one subjected to rigid inspection and laid in hydraulic cement. The drift rises from the shaft to centre of river on a grade of 1 ft. in 1,000. The line was located above ground by triangulation, and transferred below by means of plumb-bob in water, suspended down shaft by fine silk cords. As the distance between them was so short that an error of 1-32 in. would throw the work out 6 or 8 in. at middle of river, a drift has been run back from the shaft 50 ft., and an iron tube is being sunk to its end, in which a plumb-line may be suspended and a longer range obtained. The drainage drift is not straight across the river, but has two short curves in it. Work has been commenced on shaft at Windsor, and tunnel will be excavated from it to meet that being worked from Detroit side. It is anticipated that the main tunnels will be surrounded their whole length with good solid ground, suitable for construction—firm blue clay. Developments have thus far been quite as favorable as was expected when the plans and estimates were prepared, and show nothing to discourage a reasonable belief that the work will be carried to a successful issue.

HOOSAC TUNNEL.—This great work made material progress in 1871. The distance from eastern portal to central shaft is 12,837 ft., and of this 5,283 ft., or one yard over a mile of heading, had been penetrated by State engineers, first April, 1869, when the present contractors took charge. This left 7,554 ft., and of this but 2,501 ft. of heading remained on first Feb., 1872. On the west side more and greater difficulties have been encountered, and there remain 4,644 ft. It is expected that the tunnel will be done and cars pass through it in autumn of 1874.

Railway connection with E. portal will be soon completed; and two miles of new R. will connect W. portal with North Adams racks.

BOOK NOTICES.

HAND-BOOK TO SOUTH AFRICA. S. W. Silver & Co., London.

This hand-book contains much useful advice and information for those about to visit the diamond and gold fields of South Africa, and it is one of a series that the Messrs. Silver have always been ready to publish for the assistance and guide of emigrants and *voyageurs*.

An excellent preface has been written by Mr. H. W. Bates, F. R. G S., giving in a concise manner the principal geographic peculiarities and formations of the country. The routes to the diamond fields are pointed out, and the best means te be adopted in furtherance of such a route as may be selected. The general advice appears to agree with that given by all who have tried the diamond fields —that it is useless to attempt to go there and prosecute diamond hunting without sufficient capital, provision being made for the return journey in the event of disappointment.

The hand-book contains the following ready rule for the determination of heights, by the use of an aneroid barometer: If you require only to ascertain the difference of height of two places, A to B, the following is all that is necessary. Read the aneroid at A, say 30.15, take it to B, read it there, say 29.08, take it back to A, read it again, say 30.19. Then take the mean of the readings at A, and find the difference between that and the reading at B. Multiply the difference in hundredths by 9, and the result will be the difference of altitude in feet, thus:

$$\frac{30.15+30.19}{2} = 30.17-29.08 = 1.09,$$

then $109 \times 9 = 981$, height in feet.

ESTIMATES AND DIAGRAMS OF RAILWAY BRIDGES. By J. W. GROVER, C. E. Second Edition, enlarged. London: Spon. For sale by Van Nostrand.

These estimates and diagrams include railway bridges for turnpike, public and occupation roads, in the embankments of double and single lines and cuttings of double lines, with form for calculating quantities in skew structures, etc.; also culverts of various dimensions. The author, in this edition of a strictly professional and reliable work, has added some good examples of station works, as actually executed, with their costs, which will be found useful.

TABLES FOR PLATE-LAYERS. By WILLIAM DONALDSON, M.A., A.I.C.E. London: Spon. For sale by Van Nostrand.

These tables are compiled from the formulæ of the work on "Switches and Crossings," by the same author, and lately noticed in our columns. The tables, relating to various gauges, single and mixed, are preceded by an explanation. The volume must be a useful one to plate-layers; it is cased in stout boards, and can be opened without breaking the back of the book, which is what cannot be said of every volume nowadays.

PRACTICAL GEOMETRY FOR THE ARCHITECT, ENGINEER, SURVEYOR, AND MECHANIC. By E. WYNDHAM TARN, M.A., Architect. London: Lockwood & Co., 1871.

This is a work of remarkable merit in its class, and will be found of real use by those to whom it is addressed. The rules laid down are simplified, and they are fully illustrated by 164 wood engravings. We should have been glad to find a separate chapter on the theory of domes, concerning which Mr. Tarn has elsewhere shown himself well informed.

TEXT-BOOK OF GEOMETRY. Part I. By T. S. ALDIS, M. A., Professor of Mathematics, Newcastle College of Science. London: Bell and Daldy, 1871.

This is an attempt to reconstruct the contents of the first three books of Euclid. The author, to make his treatment of the subject valuable as an exercise in mental rather than mechanical reasoning, has shortened the proofs given by omitting minor points, which are left as exercises for the student. The work being theoretical, hypothetical constructions are throughout employed, and problems are given as exercises, the proofs of the constructions being in most cases left to the student. Professor Aldis divides his book—which he proposes to continue—into three sections. The first of these treats of Angles, Parallels, Triangles, and Theorems of Equality and Inequality. The second, of Parallelograms and Equivalent Figures; and the third, of Circles and Polygons and their various properties. The book is worthy of the notice of Geometricians as being one of the most respectable attempts among many barren failures to supersede Euclid as a text-book. The development of the author's plan must have cost him much time and reflection, and the result is not at all discreditable to his distinguished position as a mathematician. We have said enough to indicate the character of Mr. Aldis's present effort; we shall have to wait till we see its extension before we can be able to give an opinion as to the character of his scheme as an educational method.

The Year Book of Facts, 1872. By John Timbs. London: Lockwood & Co. For sale by Van Nostrand.

This work, which has been before the public so many years, is too well known to require any eulogium at our hands. The volume for 1871 is just published, and contains the usual notices pertaining to science and art. We would suggest in another volume a little more variety in the quotations from newspapers.

Plain Directions for the Construction and Erection of Lightning-rods. By John Phin, C. E. New York: The Handicraft Publication Company. For sale by Van Nostrand.

This little hand-book will prove of signal service, in extending a knowledge of the laws of Atmospheric Electricity, and so serve to check the frauds perpetrated in the rural districts by charlatans who engage in the business of erecting lightning-rods.

The author writes much in the interest of practical science, always concisely and correctly.

Pocket-Book of Mechanics and Engineering. By John W. Nystrom, C. E. Philadelphia: J. B. Lippincott & Co. For Sale by Van Nostrand.

This is a revision and an enlargement of a well-known book, which in this issue appears as the eleventh edition. Nothing seems to be wanting which an engineer expects to find in his pocket-book. The tables are more than ordinarily complete, both Natural and Logarithmic. Trigonometric functions are given for single minutes and to five places of decimals. Not the least valuable portion is that relating to the steam engine, which extends over 32 pages. The volume contains 510 pages.

An Elementary and Practical Treatise on Bridge Building. By S. Whipple, C. E. New York: D. Van Nostrand.

A new work from the pioneer in scientific bridge building in this country is an event worth noting.

Only in the first chapters does the present work bear the familiar features of the older editions; the book is greatly enlarged by the addition of much new and altogether valuable matter.

Discussions of the principles of construction of the Fink, Bollman, Post, and Warren Trusses, are given in terms that cannot be misunderstood even by readers who habitually shun mathematical formulæ.

No work within our knowledge is so thoroughly practical in the matter of details of selection and distribution of material, as well as in uniting of the different members of a truss. That clearness of elucidation which recommended the old work so strongly to young engineers, is equally a characteristic of the present edition. It is printed in excellent type and contains an abundance of illustrations interspersed with the text.

MISCELLANEOUS.

The durability of the framed timbers of buildings is very considerable. The trusses of the old part of the roof of the Basilica of St. Paul, at Rome, were framed in 816, and were sound and good in 1814, a space of nearly a thousand years. These trusses are of fir. The timber work of the external domes of the Church of St. Mark, at Venice, is more than 840 years old, and is still in a good state. And Alberti observed the gates of cypress to the Church of St. Peter, at Rome, to be whole and sound after being up nearly 600 years. The inner roof of the Chapel of St. Nicholas, King's Lynn, Norfolk, is of oak, and was constructed about 500 years ago. Daviller states, as an instance of the durability of fir, that the large dormitory of the Jacobins' Convent, at Paris, had been executed in fir, and lasted 400 years.

A crucible for melting metal has been invented, which consists in providing the ordinary crucible of plumbago or other substance with a flue or passage from the bottom to the top, for allowing the heat to act upon the centre of the mass of metal contained in the crucible more directly than it otherwise can. This passage is surrounded by a shell or tube of the same material of which the crucible is made. The inventor also grooves, or indents, or constructs the sides of the crucible, both inside and out, so as to form projections, to interlock with the paste, or clay, or other substance with which the crucible is coated, to cause the coatings to be retained much longer than they now are, thereby preserving the crucible much longer, and reducing the cost of melting steel or other metals.

The Suez Canal.—The Suez Canal Company held a special general meeting on the 12th inst., to receive the report of the council, and to consider some new propositions, or rather to be informed of fresh decisions of the council.

The report respecting the working of the canal is very satisfactory. The number of ships passing through the canal has increased from 765 in the whole year of 1871, to 200 in the first two months of 1872; and the total recipts from a little over five millions of francs for the former, to two-and-a-half millions for the latter period. The cost of working has at the same time been reduced, and the promised result is that there will be at the end of the present year a clear balance of, at least, £89,200 on the twelve months' working.

The canal is now reported to have an average depth from the extremity of the jetties of Port Said to the roads of Suez, of no less than 8.30 metres, in proof of which the transit of the Nebraska is mentioned, a ship of 2,983 tons, and drawing 7.21 metres of water. The reports speak also of the passage without difficulty of the great transports of the English Government, of 3,000 tons burthen, and one of which had 1,421 soldiers on board; of the Peiho of the Massageries Company, making the transit in less than 14, and the Persia packet in less than 13 hours.

The engineers report, after an experience of two years, that the maintenance of the canal proper will entail an anual expenditure of £33,000 per 500,000 cubic metres.

Another fact on which the company is to be congratulated, is that the council has only issued twelve millions of the twenty million loan voted in July last.

At the Southern Railway terminus at Vienna, the water supplying the locomotives is rendered soft by the use of lime water, and is subsequently passed through filters of peculiar construction to remove the precipitate. In the table below are given (1) the solid contents of 10,000 parts of the water before treatment; (2) that of the same amount after treatment; (3) percentage composition of the boiler scale from the hard water; (4) that of the mud for the softened water; and (5) the composition of the contents of the filters.

	1.	2.	3.	4.	5.
Chloride of sodium	0.8029	0.8237	......	....	....
Chloride of magnesium	0.2986	0.2892	....	....	....
Sulphate of lime ..	1.9398	1 6796	2.29	76.60	7.92
Carbonate of lime.	1 8830	0.0292	73.87	1.41	69.71
Carbonate of magnesia	1 4729	0 0178	19 40	1.57	10.96
Oxides of iron and alumina	......	.....	3.07	1 52	3.46
Silica.............	0 0715	0 0580	......	....	....
Sand	......	....	0 83	0 65	0 63
Organic matter. .	1.9853	1.4370	0 93	18.23	5 57
	8.4540	4.3345	100 39	99.98	98.25

It is seen that the carbonates of lime and magnesia are almost entirely, and the sulphate of lime (gypsum) is partially, removed by the process, while the amounts of organic matter and silica are considerably diminished. If the quantity of sulphate of lime be more considerable, the water may be freed from it after the lime treatment by the addition of soda solution, which converts the remaining gypsum, the chloride of magnesium, and chloride of calcium, if present, into an insoluble form that can be separated by means of the filter.

It seems that the proposition to tunnel under the English Channel is not to end in talk, after all. The company registered in London on the 15th ult., is about to excavate a trial shaft and driftway on the English side, and, if the scheme is found practicable, push the work on until it reaches the shores of France. A tunnel 22 miles long, and under water at that, is a formidable undertaking, but it is evident the company mean business, since the experimental section to be built, which will have no value whatever except as a part of the finished work, will cost £2,000,000. So much capital is not likely to be wasted in the hands of English engineers, and when the work is once fairly undertaken, we shall expect to see it completed.

Granite Works of the Ancients.—We quote the following from an exceedingly interesting account of the colossal granite structures of ancient Egypt, India, and South America, which appears in the current number of the "People's Magazine:" "The art of carving in granite has never been carried to higher perfection than on the continent of India. At Chillambaram, also in the Carnatic, and on the Coromandel coast, is a congeries of temples, representing the sacred Mount of Meru. Here are 7 lofty walls, one within the other, round the central quadrangle, and as many pyramidal gateways in the midst of each side, which form the limbs of a vast cross; consisting altogether of 28 pyramids. There are consequently 14 in a line, which extend more than a mile in one continuous direction! Nor are these the only wonders associated with this metropolis of pyramids. The interior ornaments are in harmony with the whole; from the nave of one of the principal structures there hang, on the tops of 4 buttresses, festoons of chains, in length about 548 ft. Each garland, consisting of 20 links, is made of one piece of granite, 60 ft. long; the links themselves are monstrous rings, 32 in. in circumference, and polished as smooth as glass. Compared with the monolith temples of granite at Mahabalipuram, which is likewise situated on the Coromandel coast, those in Egypt sink into insignificance. The rocks thereabouts are composed of a hard gray granite, containing quartz, mica, and felspar, with a few crystals of hornblende interspersed. Many have been hollowed out by art, and sculptured into temples with spirited bas-reliefs, representing episodes in Hindoo history and mythology, and supported by graceful columns; all carved from the solid rock. Detached masses have been cut into shapes of elephants, tigers, lions, bulls, cats, monkeys, and various nondescript monsters, and colossal statues of gods, one of which, namely, that of Ganesa, being 30 ft. high. The southernmost of the temples is about 40 ft. in height, 27 ft. in breadth, and nearly the same in length; the exterior being covered with elaborate sculptures. The adjoining edifice is about 49 ft. in length, and in breadth 25 ft.; it is rent by natural causes from summit to base. According to the local Brahminical tradition, these wonderful sculptures were executed by 4,000 workmen, who had come from the north, and returned before their completion. From a careful examination, it is evident that almost all the enormous mass of sculpture and carving that adorns this city of monolith temples and colossi, must have been performed without the aid of fire—with the hammer, chisel, lever, and wedge alone; and this is one of the hardest rocks in the world!"

The Yokohama and Tokio Gas Company is formed for the purpose of lighting the principal city and chief commercial town in Japan with gas. This is another proof of the eagerness with which this people are availing themselves of the applications of science, which have been, until of late years, confined to Europe and America.

CALORIMETER.

Constructed by CAPTAIN JOHN ERICSSON.

Fig. 1.

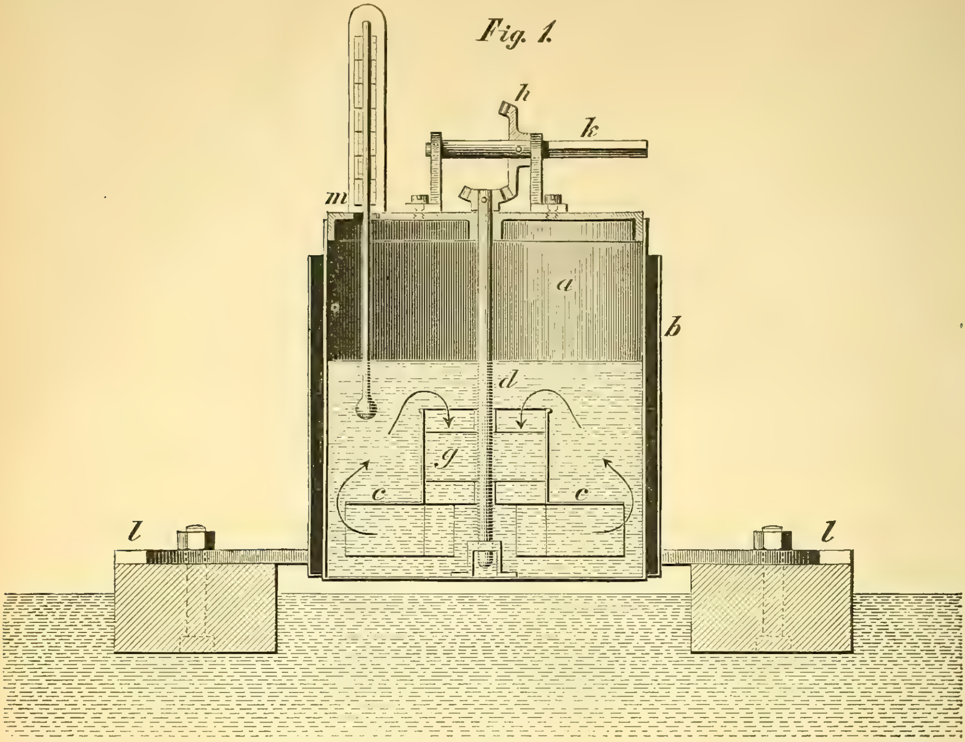
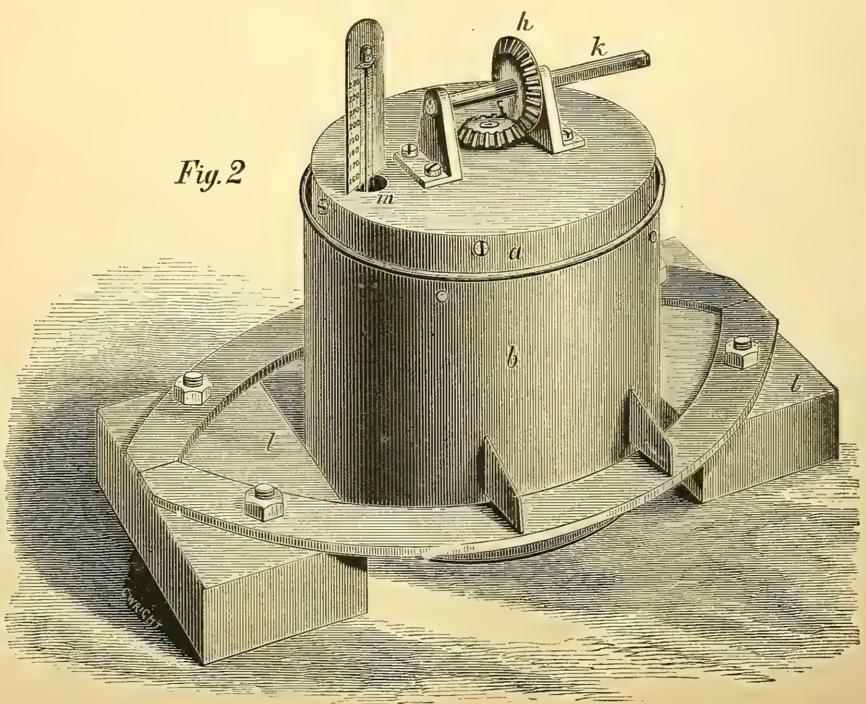


Fig. 2



VAN NOSTRAND'S
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THE TEMPERATURE OF THE SURFACE OF THE SUN.

By Captain JOHN ERICSSON.

From "Nature."

See Frontispiece.

It will be recollected that Messrs. M. E. Vicaire and Sainte-Claire Deville read some papers before the Academy of Sciences at Paris, last January, showing that the temperature of the solar surface does not exceed that produced by the combustion of organic substances. Their reasoning being based on the law of radiant heat, established by the investigations of Dulong and Petit, I have, in the meantime, instituted a series of experiments on a comparatively large scale, in order to test the correctness of the said law. Accordingly, the dynamic energy developed by the radiation of a mass of fused iron weighing 7,000 lbs. raised by "overheating" in the furnace to a temperature of 3,000 deg. F., has been carefully measured.

Sir Isaac Newton assumed that the quantity of heat lost or gained by a body in a given time is proportional to the difference between its temperature and that of the surrounding medium. Some eminent scientists, however, accepting Dulong's conclusions and formula, assert positively that the stated assumption is incorrect. In so doing they apparently overlook the conditions inseparable from the Newtonian doctrine, namely, that the conducting power of the radiating body should be perfect; that at every instant the temperature pervading the interior mass should be transmitted to the surface.* It needs no demonstration to prove that if the conducting power of a body be so perfect that the temperature of the centre is at all times the same as that of the surface—in other words, that the fall of temperature at the centre, occasioned by radiation, is as rapid as the fall of temperature at the surface, the rate of cooling of such a body will be very different from that observed by Dulong and Petit. The investigation instituted by those experimentalists has in reality established only the degree of conductivity of the radiators employed, under certain conditions, but by no means their true radiant energy at given temperatures. M. E. Vicaire and Sainte-Claire Deville, therefore, commit a serious mistake in assuming that the quantity of heat transmitted by the radiation of incandescent bodies at high temperatures has been determined. It may be observed that the relation between the time of cooling and

* The writer has just completed a set of experiments with a spherical radiator, 2.75 in. in diameter, composed of very thin hammered copper, charged with water kept in motion by a wheel applied within the sphere, revolving at a rate of 30 turns per minute, the centrifugal action of which brings the particles of the central portion of the fluid so rapidly in contact with the thin spherical shell, that the apparently absurd condition of perfect conductivity has been practically fulfilled. The result of carefully conducted experiments with this radiator, enclosed in an exhausted vessel kept at a constant temperature, has established that Newton's law relating to radiant heat, up to a differential temperature of 100 deg. Fahr. (beyond which the investigation has not extended), is rigorously correct. The subject will be fully discussed in a future article.

the *quantity* of heat transmitted by radiation which Dulong and Petit established, also misled Pouillet regarding the temperature of the solar surface, which he computed at 1,461 deg. C., or at most 1,761 deg. C. It will be well to bear in mind that Pouillet had himself ascertained with considerable accuracy the temperature produced by solar radiation on the surface of the earth; and also the retardation suffered during the passage of the rays through the terrestrial atmosphere. He was therefore able to demonstrate that the dynamic energy developed by solar heat amounts to nearly 300,000 thermal units per minute for each sq. ft. of the surface of the sun. Considering the imperfect means employed by Pouillet, his "pyrheliometer," the exactness of his determination of solar energy is remarkable. The truth is, however, that the near approach to exactness was somewhat fortuitous, the eminent physicist having underrated the energy of radiant heat on the surface of the earth, while proportionately over-estimating the retarding influence of the terrestrial atmosphere. The true dynamic energy developed by radiation at the surface of the sun, exclusive of the absorption of the solar atmosphere—no doubt exceedingly small—determined by the solar calorimeter mentioned in a previous article, is 312,500 thermal units per minute upon an area of 1 sq. ft. It will be proper to notice that this amount is not a mean result of a number of observations, but the greatest energy developed at any time during observations continued upwards of 3 years, namely, February 28, 1871. It will be proper to add that this result has been withheld from publication until it could be verified by a second observation indicating an equal energy. Fortunately the sky at noon, March 7, 1872, proved to be as clear as on the previous occasion referred to, the indicated energy differing only a few hundred units from that developed February 28, 1871.

Temperature being a true index of molecular and mechanical energy, conclusively established by the exact relation between the degree of heat and the expansive force of permanent gases under constant volume, it is surprising that Pouillet did not perceive that an intensity of 1,461 deg. C. or 1,761 deg. C., could not possibly develop on a single sq. ft. of surface the enormous energy represented by 300,000 thermal units per minute. M. Vicaire, adopting, like Pouillet, Dulong's formula, states in the paper presented to the French Academy that "an increase of 600 deg. is sufficient to increase the radiation a hundred fold;" and that Pouillet has verified Dulong's law to more than 1,000 deg. "Supposing," he observes, "that beyond this temperature the law ceases to be true, it cannot be absolutely remote from the truth for the temperatures of from 1,400 to 1,500 deg., which we deduce by adopting the law." Sainte-Claire Deville concludes his essay on solar temperature thus: "In accordance with my first estimate, I believe that this temperature will not be found far removed from 2,500 to 2,800 deg., the numbers which result from the experiments of M. Bunsen, and those published long ago by M. Debray and myself." The French *savans* then agree that the temperature of the surface of the sun does not exceed the intensity produced by the combustion of organic substances, their grounds for this assumption being, as we have seen, Dulong's formula relating to the velocity of cooling at high temperatures. But Dulong and Petit did not carry their investigations practically beyond the temperature of boiling mercury; hence their formula relating to high temperatures is mere theory, the soundness of which we have now been enabled to test most effectually by measuring the radiant power of a mass of fused metal raised to a temperature of 3,000 deg. F., 30 in. in depth, presenting an area of 900 sq. in.

Before describing the means which have been employed in measuring its radiant power, let us briefly consider the condition of the fused mass during the experiments. In the first place, the temperature has been sufficiently high to produce an intense white light, luminous rays of great brilliancy being emitted by the radiant surface during the trial; (2) the bulk of the fused mass being adequate, the intensity of radiation has been sustained without appreciable diminution during the time required for observation; (3) the temperature being higher than that which the French investigations assign to the surface of the sun, while the bulk, as stated, is sufficient to maintain the temperature of the fused mass, it may be reasonably asked, why an area of 1 sq.

ft. of our experimental radiator should not emit as much heat in a given time as an equal area on the solar surface, if its temperature be that assumed by Pouillet? It may be positively asserted, moreover, that an increase of the dimensions of our radiator to any extent, laterally or vertically, could not augment the intensity or the dynamic energy developed by a given area. Again, Dulong's formula, as applied by scientists, shows that the emissive power of a *metallic* radiator raised to a temperature of 3,000 deg., reaches the enormous solar emission computed by Pouillet.

Let us now briefly examine the calorimeter constructed for ascertaining the mechanical energy developed by the radiation of the fused mass under consideration. Fig. 1 represents a vertical section, and Fig. 2 a perspective view; *a* is a cylindrical boiler, having a flat bottom, composed of thin sheet-iron 0.012 in. thick, coated with lampblack. The cylindrical part of this boiler is surrounded by a concentric casing *b*, the intervening space being filled with a fire-proof non conducting substance. A horizontal wheel *c c*, provided with six radial paddles, is applied within the boiler, attached to a vertical axle, *d*. An open cylindrical trunk, *g*, is secured to the perforated disc which supports the paddles. The vertical axle passes through the top of the boiler, a conical pinion being secured to its upper termination. By means of a vertical cog-wheel, *h*, attached to the horizontal axle *k*, and geared into the conical pinion, rotary motion is communicated to the paddles. The centrifugal action of the latter will obviously cause a rapid and uniform circulation of the water contained in the boiler—indispensable to prevent the intense radiant heat from burning the bottom. The boiler and mechanism thus described are secured to a raft, *l l*, composed of firebricks floating on the top of the fluid metal. By this means it has been found practicable to keep the bottom of the boiler at a given distance, very near the surface of the fused mass, while by moving the raft from point to point, during the observation, irregular heating resulting from the reduction of temperature of the surface of the metal, under the bottom of the calorimeter, has been prevented. The radiant heat being too intense to admit of the axle *k* being turned directly by hand, an intervening shaft, 8 ft. long, provided with a crank handle at the outer end, has been employed for keeping up the rotation of the paddle-wheel during the trial. It is scarcely necessary to observe, that the intervening shaft should be coupled to the gear work by means of a "universal joint," to admit of the necessary movement of the raft. The experiment, repeated several times, has been conducted in accordance with the following explanation. The boiler being charged, the paddle-wheel should be turned at a moderate speed while observing the temperature of the water, the thermometer employed for this purpose being introduced through an opening, *m*, at the top of the boiler. The temperature being ascertained, the instrument should be quickly placed on the raft, and the time noted. As soon as vapor is observed to escape through the opening at *m*, the instrument must be instantly removed, the time again noted, and the temperature of the water within the boiler ascertained. It will be well to keep the paddle-wheel in motion until the last observation has been concluded.

The temperature of the fused metal having been as high during our experiments as that of the solar surface computed by Pouillet and his followers, while the thin substance composing the bottom of the calorimeter has been brought almost in contact with, and consequently received the entire energy transmitted by, the radiant surface, the reader will be anxious to learn what amount of dynamic energy has been communicated in a given time, on a given area. The desired information is contained in the following brief statement:—The necessary corrections being made for heat absorbed by the materials composing the paddle-wheel, etc., the instituted test shows that the temperature of a quantity of water weighing 10 lbs. avoirdupois has been elevated 121 deg. F. in 164 seconds (2.73 min.), the area exposed to the radiant heat being 63 sq. in. Hence a dynamic energy $\frac{10\times121}{2.73} \times\frac{144}{63} = 1013$ thermal units per min., has been developed by the radiation from 1 sq. ft. of the surface of the fused metal maintained at 3,000 deg. F., against 312,500 units developed by the radiation of 1 sq. ft. of the solar surface, the temperature of which, agreeably to the calculations of the French *savans*, is less than that of our experimental radiator.

Having thus ascertained practically the amount of dynamic energy developed by the radiation of a metallic body raised to the high temperature of 3,000 deg., we have only to show in a similar manner the amount of energy developed by a metallic radiator of a low temperature, to be enabled to demonstrate the correctness or fallacy of Dulong's formula. Numerous experiments have been made for this purpose with apparatus of different forms, the results having proved substantially alike. The device most readily described consists of a spherical vessel charged with water, suspended within an exhausted spherical enclosure, kept at a constant temperature. Repeated trials show that when the differential temperature is 65 deg., the enclosure being maintained at 60 deg., while the sphere is 125 deg., the dynamic energy transmitted to the enclosure by a sphere the convex area of which is 1 sq. ft., amounts to 5.22 thermal units per minute. The accuracy of this determination is confirmed by the fact that during the summer solstice, at noon, when the sun's differential radiant intensity is 65 deg., the solar calorimeter indicates a dynamic energy of 5.12 units per minute on 1 sq. ft. of surface.

Our practical investigations, then, show that a differential temperature of 3,000 deg. develops by radiation a dynamic energy of 1,013 thermal units per minute upon an area of 1 sq. ft.; and that a differential temperature of 65 deg. develops 5.22 units per minute upon an equal area. The ratio of radiant energy at the first mentioned intensity will therefore amount to $\frac{1013}{3000} = 0.337$ unit for each degree of differential temperature; while for the low intensity it will be $\frac{5.22}{65} = 0.080$ unit for each degree of differential temperature. Consequently, the ratio of the radiating energy will be $\frac{0.337}{0.080} = 4.21$ times greater at 3,000 deg. than at 65 deg. Now, M. Vicaire, on the authority of Dulong, states that the ratio will be a hundred fold greater for an increase of only 600 deg. According to Newton's theory, based on dynamic laws, the proportion between the differential temperature and the radiant energy of bodies is constant; while Dulong and Petit, basing their conclusions upon an erroneous estimate of the time of cooling, assert that the ratio of energy increases several thousand times when the temperature is increased from 65 to 3,000 deg. Newton, then, as our experiments prove, is incomparably nearer the truth than the French experimenters; and possibly future research will prove that his law, when properly applied, will be found absolutely correct. It should be mentioned that the result of our experiments with the fused metal compared with the result of other experiments with solid metals at various temperatures, show that the emissive power of cast iron is relatively greater in a state of fusion than when solid, or merely incandescent. This observed increase of emissive power, now being thoroughly investigated, will no doubt account for the deviation from the Newtonian law indicated by the preceding comparison, which, let us recollect, is based upon the difference of radiant energy of fused metal at 3,000 deg., and solid metal at 65 deg. Considering this extreme range of temperature, and the totally different conditions of the radiators, the observed discrepancy is not too great to admit of satisfactory explanation.

The fallacy of Dulong's formula relating to high temperatures having been conclusively shown, it will not be necessary to examine the calculations of Messrs. M. E. Vicaire and Sainte-Claire Deville, presented to the Academy of Sciences at Paris. Besides, the question of solar temperature cannot be properly investigated without considering the leading points connected with the propagation of radiant heat through space—a subject of too wide a range to be discussed in this article. It should, however, be mentioned that the result of the measurement of solar intensity, March 7, 1872, before referred to, proves the correctness of our previous demonstrations, showing that the temperature of the surface of the sun is at least 4,036,000 F.

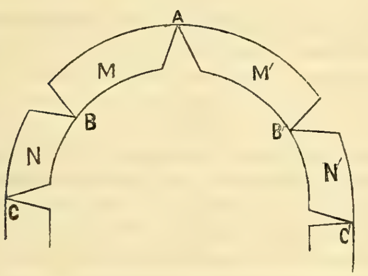
TELEGRAPHY IN FRENCH RIVERS.—Workmen have taken up two telegraphic cables laid down in the Seine between Rouen and Paris, shortly before the siege of Paris, to enable the capital, if invested, to communicate with the provinces.

THE STABILITY OF ARCHES.

Translated from "Sonnet, Dictionaire des Mathematiques Appliquées."

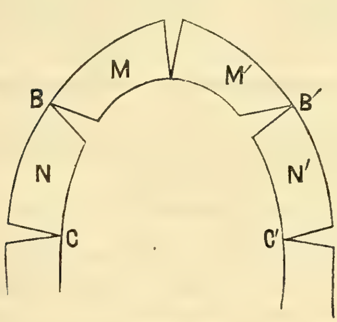
When an arch is about to give way, the effects are generally those represented in Fig. 1. At the crown, it opens on the side

Fig. 1.



of the intrados; on the flanks, at the extrados; at the springings, on the side of the intrados. It separates into 4 parts, M, M′, N, N′. The first two turn about the points B and B′, while the others fall outward, turning about C and C′. If the piers are not sufficiently stable they may turn with N and N′. In this case the rotation is about the outer edges of the piers. Again the piers may slide horizontally, instead of turning. More rarely an effect the inverse of the above is observed, as shown in Fig. 2. At the crown the open-

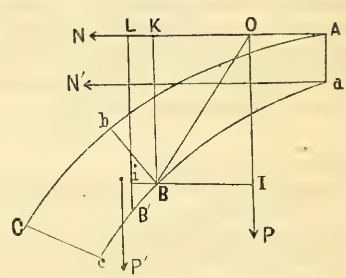
Fig. 2.



ing takes place at the extrados; on the sides, at the intrados; and on the side of the extrados at the springings. In this case the two upper portions rise about the edges B and B′; and the lower portions fall inward about C and C′. This kind of rupture happens in arches that are slender, high, and loaded heavily at the sides. To prevent this, pendant key-stones are employed, intended to increase the weight at the crown; and at the same time serving to receive ornament, as in Gothic churches.

I. That an arch may be in equilibrium none of the effects above described should ensue; and the theory of the thrust of arches aims to discover the conditions by which one may be assured of their stability. In case of an arch symmetrical with reference to a vertical plane through the intrados or extrados, one half of the arch is supposed to be removed, its place being taken by that of the reaction force. This reaction is necesarily horizontal, and perpendicular to the generatrices. Suppose Figs. 1 and 2 to represent a right section through the middle of the length. The mutual actions of the parts may be regarded as acting at N; these must be equal and opposed; and, as they are symmetrical with reference to the vertical at A, they must be horizontal and must act in the plane of the figure.

Fig. 3.



Let N (Fig. 3) = reaction of right half.
" h = its distance from B.
" H = " " " C.
" P = the resultant of exterior vertical forces acting on A B.
" p = distance of line of action of P from B.
" q = " " " " " C.
" P′ = resultant of exterior forces acting vertically on B C.
" p' = distance of P′ from C.
" R = absolute value of mutual reaction between A B and B C.
" R_x = horizontal projection of R.
" R_y = vertical " " "
" R′ = reaction of pier upon B C.
" R'_x and R'_y = projections of R′.

For the equilibrium of the part AB we have

$$R_x = N \text{ and } R_y = P \qquad (1.)$$

and, taking moments with reference to the axis projected at B,

$$N h = P p \text{ or } N = \frac{P p}{h} \qquad (2.)$$

For the equilibrium of the semi-arch

$$R'_x = N \text{ and } R'_y = P + P' \qquad (3.)$$

and, taking moments with reference to the axis projected at C,

$$N H = P' q + P' p'$$
$$\therefore N = \frac{P q + P' p'}{H} \qquad (4.)$$

The first of the equations (3) shows that the horizontal reaction is transmitted to the abutment and is the force constituting the thrust. The second shows that the abutment also supports the weight of the arch and its load. The values (2) and (4) being equal,

$$\frac{P p}{h} = \frac{P q + P' p'}{H} \qquad (5.)$$

If this equation is not satisfied the static equilibrium of the arch is not assured. If it holds, then (2) or (4) give the amount of thrust. Finally equation (1) gives the components of the reaction R at B, and consequently the value of R itself.

II. The preceding calculation supposes the position of the point B to be known, *i. e.*, the joint of rupture B*b*. This position can be approximately determined by one of several methods. Suppose (in Fig. 3) A*a*, B*b*, repesents the whole of the first n voussoirs, reckoning from the crown A:—

P = their weight and load.
p = distance of the resultant vertical of this weight to B.
N = horizontal reaction at A.
h = distance of line of N from B.

That the arch may not open along B*b*, turning about B, we must have

$$N h > \text{ or } = P p.$$
$$i.\ e.\ N > \text{ or } = \frac{P p}{h}$$

Thus $\frac{P p}{h}$ is the inferior limit of the force N, in order that the rupture may not take place along B*b*. By determining this value for different values according to the number of voussoirs taken into account, the joint corresponding to the maximum value is found; and this is the joint of rupture.

The following method may be employed. Differentiate this expression, $\frac{P p}{h}$, making P, p and h vary, and make equal to zero.

$$h\,(P\,d p + p\,d P) - P\,p\,d h = 0.$$
$$h\,d p + h\,p\,\frac{d P}{P} - p\,d h = 0$$

But d P, which is proportional to the increase of volume of the arch, is an infinitesimal of the third order, while $d\,p$ and $d\,h$ are of the first. Hence

$$\frac{d p}{d h} = \frac{p}{h}$$

But if B′ is a point of the intrados infinitely near B, we have

$$p = B I,\ h = I O,\ d p = B i,\ d h = B' i.$$
$$\therefore \frac{B i}{B' i} = \frac{B I}{I O}$$

It follows that B O is in a right line with the element B B′; *i. e.*, it is a tangent to the intrados curve at B. Hence the joint of rupture may be determined by finding the point of the intrados where the tangent is drawn which meets the horizontal at its intersection with the line of P.

M. Petit has made out tables of values of the angle of rupture for a circular arch. We give an extract for an arch.

R = radius of extrados.
r = radius of intrados.
a = angle of rupture.

$\frac{R}{r}$	a	$\frac{R}{r}$	a	$\frac{R}{r}$	a	$\frac{R}{r}$	a
	° ′		° ′		° ′		° ′
2.00	57 17	1.60	63 49	1.40	63 48	1.20	59 41
1.90	59 37	1.55	64 3	1.35	63 19	1.15	57 1
1.80	61 24	1.50	64 9	1.30	62 14	1.10	53 15
1.70	62 53	1.45	64 5	1 25	61 15	1.05	46 32

$\frac{R}{r}$1, 5 gives the maximum angle of rupture 64° 9′.

For arches extradosed horizontally we have the following table :

$\frac{R}{r}$	a	$\frac{R}{r}$	a	$\frac{R}{r}$	a	$\frac{R}{r}$	a
	°		°		°		°
2.00	36	1.60	52	1.40	59	1.20	63
1.90	39	1.55	54	1.35	60	1.15	64
1.80	44	1.50	56	1.30	61	1.10	65
1.70	48	1.45	57	1.25	62	1.05	69

In this case the angle of rupture constantly increases with the value of $\frac{R}{r}$; that is, the joint of rupture moves further from the crown as the arch becomes more slender.

In arches with elliptical intrados, the point B, where the joint of rupture meets the ellipse, is sensibly at the same height above the springing, as in a circular arch with the same thickness at the crown and with radius of intrados equal to the semi-minor axis of the ellipse.

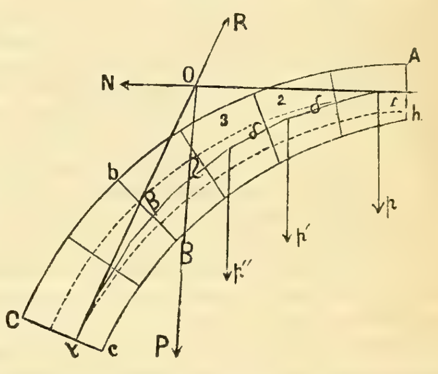
The same observation applies to *basket-handle* arches. In circular arches, properly speaking, there is no joint of rupture; since in practice the semi-angle of span, *i. e.* the angle between the radius drawn from the point of springing and the vertical, is generally smaller than the corresponding of rupture in a full centre-arch, having the same radii of intrados and extrados.

III. Instead of a sinking there may be a rising of the crown; then, instead of supposing the arch to open at *a*, *b*, *c*, Fig. 3, the points assumed are A, B, C. Rotation there takes place about *b* and *c*. By a process similar to the above we obtain the horizontal reaction N′ acting at *a*; this gives a second limit of thrust, which is larger than N since the distance of P from *b* is greater than that of *p*, while the distance of N′ from the same point is less than *h*. In a state of permanent equilibrium the reaction upon the joint A*a*, is applied at neither A, nor *a*, but at some unknown intermediate point; and its value lies between N and N′. The problem therefore is indeterminate, but this indetermination can be restricted within very narrow limits, if, instead of regarding the parts as incompressible, we take into account the compressions due to their mutual reactions. That is, the problem becomes definite, by treating it not only from a statical point of view, but also with regard to the stability of construction depending on the limited resistance of the materials employed. But, for this, it is necessary to admit the hypotheses relative to about the laws according to which pressure is distributed among the points of a plane surface of contact; and the consequence due to the fact, that, in order that there be no negative resistance at any point, it is necessary that the resultant of normal pressures, should not be applied at any point of the surface distant from an edge less than one-third the width of the prism measured at right angles to the edge.

Applying these considerations, in case of sinking of the crown, the point of application of the horizontal force N should be taken at a distance from A, equal to one-third the depth of the crown; in case of rising, the point is taken at the same distance measured from *a*. These two hypotheses will give two values of N, much more approximate than those obtained by the former methods; and between these two values, the actual value must lie. The same considerations apply at all the joints; so that by dividing each into three equal parts, and by joining with a continuous curve the points lying nearer the intrados, and by another curve those lying nearer the extrados, the limiting space of the curve of pressure is obtained.

IV. All indetermination is avoided by the use of the following graphic method, due to M. Méry.

FIG. 4.



Let A, C, *c*, *a*, (Fig. 4), be a semi-arch, of which the stability is to be determined. Take in the joint A *h*, a point *a* at one-third the depth from A; in like manner take γ in C*c*. Let P be the resultant of exterior forces acting on the arch, including its own weight. Through *a* draw a horizontal line in the direction of the thrust N, cutting P at O. Join *o* γ, and this is the direction of the reaction R of the abutment. The semi-arch being maintained in equilibrium by three forces, it follows that the three lines of their direction pass through the same point. Each must be equal and opposite to the resultant of the two others. Resolving P into two components, along O *a*, and O γ the first gives the absolute horizontal value of N, the second, the absolute value of the reaction of the abutment. Now let p, p', p'', etc., be the partial resultant of the exterior forces acting on the several voussoirs taken in order from the crown. Voussoir 1 is in equilibrium by reason of N (which is known), p and the reaction r of 2 upon 1. Constructing the resultant of N and p, and reversing it, we have the reaction r; in its true direction it is r_1, the action of 1 on 2. Voussoir 2 is equilibrated by the force r_1, the force p, and the reaction, r^1 of 3 upon 2. The resultant r^1_1, and r^1 are found as before. Continuing this process through the successive voussoirs, the reaction of the voussoir next to the last (ρ), upon the last, is found. Compounding this with the exterior force q, we should have a resultant equal, and opposed to R. In this way the forces acting upon the successive voussoirs are completely determined. The broken line joining a, δ, ε, ζ, etc., γ, is called by Mr. Méry the curve of pressures.

That stability may be assured, it is necessary (1) that that the curve of pressure be included between the curves drawn trisecting the thickness of the joints, both on the side of the intrados and of the extrados. This is necessary, as above shown, that there may be no negative pressure at any of the joints. (2). It is necessary that, in the division of the component normal of the reactions N, r, r', r'', etc., by the surface of the corresponding joints, the result obtained should be at the most equal to the pressure which the material can resist. This limit in arches should be fixed at 50,000 kilogs. for cut stone, and 10,000 kilogs, for rubble. (3.) Again it is necessary that the angle of direction of these reactions with the joint surface should differ but little from a right angle. When one of these forces is oblique to the joint, it gives rise to a component along the joint surface which measures the tendency to sliding. The friction of stone upon stone is considerable, the co-efficient being 0.76; hence the reaction may make an angle of about 370 before sliding occurs. But it is prudent not to depend upon this resistance, as it may be much diminished, if at the time of decentring the mortar is not hardened. Hence the reactions should deviate little from the normal; and this principle especially applies to circular arches.

We observe that Mr. Méry's method makes no hypothesis with regard to the pirections of the forces p, p', p'', etc.; it is therefore applicable to all cases. The exact determination of these forces is the real difficulty met in the application of the preceding theory. If the arch supported a fluid, the pressure would be normal at every point of the extrados and would be easy to determine. If, as is generally the case, the arch bears a heavy mass of masonry, one does not know how its weight is distributed among the elements of the extrados. It is generally assumed that each voussoir sustains, in addition to its own weight, that of the material between vertical planes drawn through the generatrices which bound the particular voussoir. But it is obvious that this hypothesis is arbitrary, and that it must often be far from true. It has been proposed to take into account only the component normal to the extrados of the weight thus determined; a hypothesis just as arbitrary. Probably truth lies between these assumptions. In any event the weight of masonry should be estimated at 2,200 kilogs. to a cubic metre, and that of the surcharges at a mean of 1320 kilogs.

V. The methods described are at bottom only a system of verifications. Knowing the span and height of the arch, the curve of the intrados is determined. The thickness at the crown is determined by an empirical formula of Perronet. Let e be the required thickness and l the span of the intrados; then

$$e = 0^m,325 + 0,0347\, l.$$

The curve of the extrados is now assumed, and the investigation of the equilibrium and the stability is made. If the conditions are not satisfied the thickness is increased. If they are satisfied, trial is made to find whether they can be diminished; and thus by by repeated trials are found the dimensions most suitable, regard being had to solidity and economy of construction.

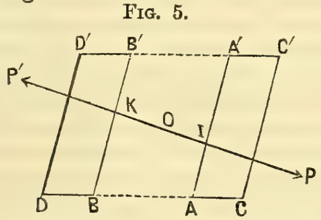
M. Ivon Villarceau, in a series of articles published in the "Revue de l'Architecture," and in a memoir entitled "Sur l' Etablissement des Arches de Pont," has attempted the problem in an inverse sense, and to determine at once the form of the intrados, the thickness at crown, and the form of the extrados; having given the span and height. He represented the conditions of the problem in equations by supposing a system of infinitely thin voussoirs, touching only at the generatrix;

and by means of laborious calculations demanding all the resources of analysis, he has constructed tables for determination of the various elements of an arch. It would be impossible for us to give his investigations in detail; but we observe that the intrados and extrados curves resulting from the theory of M. Ivon Villarceau differ little from the curves ordinarily employed; being slightly more spreading at the flanks.

VI. So far we have written only of right arches. In skew arches, at the time of decentring it is observed that the greatest contraction of material takes place in the direction of the right section; the influence is that the thrust is in a plane perpendicular to the axis of the arch. But it is not uniformly distributed through the length. This may be shown as follows:

Let ABB'A, CDD'C (Fig. 5.) represent the horizontal section at the springings of a skew arch; let O be the centre of the parallelogram.

Fig. 5.



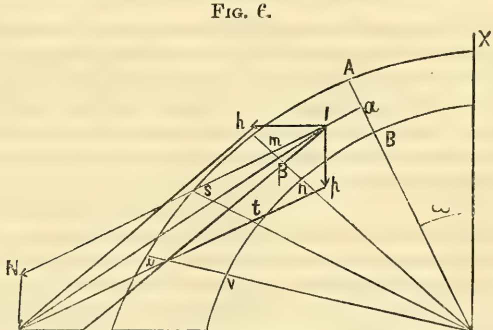
Draw through O, IK perpendicular to AA' and BB'. The total weight of the arch passes vertically through O. It can be decomposed into two others situated in the vertical plane whose trace is IK. The horizontal components are directed along IK; OP and OP' may represent these components, which constitute the thrust itself. The figure shows that the force P is nearer the acute angle A than to the obtuse angle A'; hence the thrust is unequally distributed along AA', and the angle A sustains the greatest strain. This result is independent of the coursing of the arch.

But another effect is produced in skew arches called the thrust *au vide,* and this depends on the coursing. This consists in the tendency of the voussoirs at the extremity to slide outward beyond the faces. This is apparent in the helicoidal coursing on account of the inclination of the helices which are the limits of beds of the voussoirs. It is not seen in the orthogonal coursing, especially when the cylinders which project the orthogonal trajectories on the head-plane are employed in setting the continuous joints of the head voussoirs. This is the chief advantage of this kind of arch, which is little employed because of the difficulties of execution. And it should be mentioned that in certain bridges near Paris constructed according to the orthogonal system the heads nave been strengthened by iron straps.

The most advantageous system of skew arches in respect to stability, is that composed of right arcs *en retraite;* the only inconvenience being a series of *redans* on the intrados side which have a disagreeable look.

VII. We how have to say a few words with regard to dome arches. Let A, B,

Fig. 6.



C, D (Fig. 6), represent the section of an arch of this kind made by a vertical plane through O V. Let *a*B, *mn*, *st*, *nv*, DC, be the traces of the conic joints dividing the arch. Suppose the vault divided into *n* equal slices by planes through O V, making equal angles; and that the figure shows the section of one of these made by its vertical plane of symmetry.

Let P be the weight of the upper part

of the vault (dotted). A dome generally has to bear only its own weight: if otherwise, let the load be included in P. This may be resolved into n equal forces directed in the plane of symmetry of each of the n slices, normal to the upper conical joint. If AOX=α, the component acting on AB is $\frac{P}{n}$ sin.α; acting at a, which is taken so that no negative pressure may occur in B and so that A may not be crushed. This normal N compounds with p, the weight of the first voussoir, giving a resultant R. But this does not represent the pressure of the first voussoir upon the second. The vertical faces receive pressures from adjacent voussoirs which may be regarded as normal, giving, by reason of symmetry, a horizontal resultant in the plane of the figure. Besides, the condition may be assumed that the pressure of the first upon the second voussoir is normal to the conical joint between them. Decomposing R into h horizontal, and r perpendicular to $m\ n$; the latter will represent the pressure of the first on the second, and the former will be the resultant of lateral pressures. The force n compounded with the weight p' of the second voussoir gives a resultant R′ which can be decomposed as was done with R. All the forces acting on the several voussoirs are found by continuing this process. The last force r will give the normal pressure of the last voussoir upon the upper face of the circular supporting wall; the horizontal component is the thrust.

For equilibrium and stability it is necessary: (1) that the pressures r lie between the curves AD and BC; (2) that their points of application a, B, etc., shall not be so near either edge as to risk negative pressure of crushing at the edge; (3) that when the pressure is distributed upon the bearing surface the unit pressure shall fall within the limit of safety.

For prudence, the pressures should all be normal, as domes are ordinarily thin; but if the resistance of friction is considered, the forces N, r, r', etc., may have a certain inclination to the normal.

This method is obviously but an extension of the method of M. Méry. The conical joints may be divided into 3 equivalent parts by arcs or circles described from O as centre; and the condition may be imposed that the forces N, r, r', etc., shall all be comprised within the intermediate zone. If the conditions are not fulfilled, then the thickness of the dome must be increased or the curve of the extrados must be modified. In general, both in arches and domes, the thickness at springing should be greater than at the crown.

STANDARD vs. NARROW GAUGE.

By HERMAN HAUPT, Civil Engineer.

Written for Van Nostrand's Magazine.

The writer has received letters and personal requests for an opinion in regard to the advantages claimed for narrow-gauge railways. Time will not permit a separate answer to each, and he has, therefore, concluded to dispose of them collectively by an article for the "Engineering Magazine."

Narrow gauge has some advantages as compared with standard gauge, and some disadvantages. Its merits have been greatly exaggerated.

It is not fair to compare narrow-gauge railways equipped with light rolling stock, with the standard gauge on which necessarily heavy engines are used, and credit the saving entirely to narrow gauge.

A fair comparison, so far as the question of gauge is concerned, would be to put the light engines and cars of the narrow upon the standard gauge, and then note the cost of construction and operation.

Upon this, the only true standard of comparison, some of the claims of narrow gauge appear unreasonable and absurd.

It is unquestionably true that the excessive weight of cars and engines on ordinary standard gauge roads, and the excess of dead weight in proportion to paying load, increase greatly the cost of construction and of operation; but is such excessive weight necessary? In considering the relative advantages of gauges, it is unfair to assume different conditions; but the comparison should be made with similar equipments in both.

Take then the narrow-gauge cars and engines, extend the axles and cross-pieces of car trucks $20\frac{1}{2}$ in., give the axles increased size so as to to possess equal strength, let weights remain constant, wheels, car bodies, engines, all the same in both, and then compare the two systems.

The narrow gauge will have the advantage—

1. Of allowing about $\frac{1}{4}$ of a ton more load to a car, in consequence of reduced weight of axles and cross-pieces.

2. Reduced length of cross-ties, saving from $100 to $200 per mile.

3. Reduced width of road-bed of 20 in. This would save per mile, on an embankment averaging 10 ft., $100; on a side-hill cut of earth 10 ft. at upper slope, $50; Ballasting, $250. A little saving in width of bridges, which is almost inappreciable, as the trusses are the same in both.

4. Increased facility in turning curves, This is the greatest advantage as favoring economy of construction. The difference in length between the inner and outer rail with the standard 4 ft. $8\frac{1}{2}$ in. gauge is very nearly 1 in. in 100 ft. for each degree of curvature, with a 10 deg. curve the difference in 100 ft. would be 10 in., and as the wheels are not permitted to turn on axles, there must be a slip to this extent. On a gauge of 36 in. a slip of 10 in. to 100 ft. would be due to a curve of $15\frac{1}{2}$ deg. and it is possible that a curve of $15\frac{1}{2}$ deg. on a 36 in. gauge would oppose no more resistance, than a curve of 10 deg. on a gauge of $56\frac{1}{2}$ in.

The substitution of 15 deg. curves for 10 deg. curves may, in many cases, as on steep side-hill locations, result in great economy of construction, permitting the centre line to conform to the surface where curves of 50 per cent. greater radii would involve heavy cuts and fills, but this advantage is confined to localities where sharp curves and steep side-hills are presented. On level ground, or on curves considerably within the maximum limits, the saving secured by the use of narrow gauge would not be considerable.

As regards gradients it is believed that the advocates of the narrow gauge do not claim that an engine with a given weight on drivers, will haul a greater gross load on the same inclination, or a straight line in consequence of reduced width of gauge.

Assuming, therefore, the only true standard of comparison of cars and engines of equal weight on both gauges, the advantages of narrow gauge may be stated.

1. A slight saving in weight of axles and cross-beams, and an equal addition to paying load.

2. A saving in cross-ties, road-bed and ballast, as previously stated, of say $500 per mile, on an average.

3. A saving in cost of construction consequent upon the use of sharper curves.

These savings can only be determined in each case by a comparative estimate, based on actual location, but they will not amount in the aggregate to 10 per cent. of the savings claimed by the advocates of the narrow gauge.

Economy, both in construction and operation, results from *low speed, light weight, and reduced proportion of dead to paying weight.*

The cars and engines on standard gauges are too heavy and speed too great. When engines of 10 tons were used the durability of rails was almost indefinite, and breakages of very rare occurrence.

Come back to light weight of rails and rolling stock, and moderate speeds on standard gauge roads, and the advantages claimed for narrow gauges will be much reduced.

Many of the claims of the advocates of narrow gauge are preposterous, and will not bear investigation. For example, in a pamphlet before the writer it is claimed that the 36 in. gauge willl effect a saving of 25 per cent. in right of way.

It is usual to take four rods in width, and the same quantity would no doubt be taken, even if the gauge should be reduced 20 in.; but conceding that a proportionate reduction should be made, the percentage saved would be less than 3 per cent., even assuming that the damages paid are in proportion to area of land condemned, which is far from correct.

It is also claimed that 25 per cent. is saved in ditches, and in formation of road-bed, by reduced width of 20 in. This is also extravagant, for the ditches drain the slopes and often a large area above the slopes, and are not affected by width of road-bed.

It is conceded that stability is impaired by narrow gauge when speed is high, but sufficient weight is not attached to this objection. In 1847, a part of the Susquehanna bridge on the Penna. R. R., while in progress of construction, was blown down by a high wind, and calculation proved that winds are occasionally high enough to blow over a train of cars on a level track, even of standard gauge. The tendency to blow over would be increased on a narrow gauge, particularly if a rocking motion should be communicated to cars by inequalities in the surface of the track.

These criticisms are not designed to discredit narrow-gauge roads, which are destined to play an important part in the economy of transportation; they are introducing a much needed reform, but let not the narrow gauge be credited with economies resulting from light weight and moderate speed, which are not necessarily confined to it but may be introduced with almost equal advantage on roads of standard gauge.

Narrow-gauge roads as feeders for trunk lines of standard gauge involve transhipment at their termini, and separate equipment for their operation, which cannot be transferred from one road to another with facility as needed. This is a very serious drawback to their use in coal transportation. The transhipment of coal, especially of the softer kinds, is attended with great breakage and waste, and a system which would prevent main line cars from loading at branch road collieries, will not soon be looked upon with favor where coal operations are extensively carried on.

The writer has used a wooden railroad in lumbering and other operations, which for such purposes possesses great advantages. It consists of hewed timbers 6 in. square, laid in trenches and filled in so that the surface of the timbers is flush with the surface of the road-bed. No cross-ties or rails are used, the timbers themselves form the rail. The wheels are made of wood, pieces of hard wood cut in form of circular sectors nailed to break joints, one over another, so as to give a tread of 6 in. The flange is a ring of cast iron bolted on the wheel, boxes of cast iron inserted and wedged in middle of wheel. Such tracks can be laid on common earth roads, without obstructing their use for carts or wagons; as nothing projects above the surface they are particularly valuable in railroad cuts where carts and cars can be use at the same time, without interfering with each other.

CAPACITY OF NARROW-GAUGE ROADS.

The capacity of a railroad is often limited by the facilities for handling freight at its terminus, but where such facilities are ample, the capacity will be measured by the load of the trains and the number arriving in a given time.

The question of speed affects the capacity of a given equipment, but not the capacity of the road itself. At slow speed more cars and engines must be used to carry a given tonnage; but the destructive effects of speed both on permanent way and rolling stock increase in a much higher ratio than the velocity.

The load of an engine of given weight on drivers is determined by the maximum resistance offered by grade and curvature on the division over which it travels, or by grade alone when full compensation has been made for curvature.

The interval between trains must be sufficient to switch off a train or give notice of accidents or obstruction; to guard against rear collisions, 15 min. will be assumed as a minimum.

On a freight road worked nearly to the limit of its capacity, a double track and uniform speed will be essential, and separate tracks must be provided for passenger trains requiring higher speed.

The standard freight engine on Pennsylvania Railroad weighs 75,500 lbs., weight on 6 drivers 53,000 lbs., weight of tender with coal and water 50,000 lbs. The tractive power of such an engine on a level is 1,210 tons gross load.

Assuming for narrow-gauge roads an engine with 6 drivers and no truck, weight on drivers 27,000 lbs., tender 27,000 lbs., cars as is claimed, of 2 tons carrying 6 tons. The load on different grades would be, in tons of 2,000 lbs.

	Gross load. Tons.	No. of Cars.	Freight. Tons.
Level	605	72	432
10 p. grade	425	49	294
20 "	332	38	228
30 "	275	31	186
40 "	228	25	150
50 "	197	21	126
60 "	174	18	108
70 "	155	16	96
80 "	140	14	84
90 "	128	12	72
100 "	118	11	66
110 "	109	10	60
120 "	100	9	54
130 "	95	8	48

Assume now, that the ruling gradient which determines the load of the trains on a narrow-gauge road, is 50 ft., and that higher indications are overcome by assistant engines. Two engines would carry the train over a grade of 105 ft. The capacity of the road can now be determined. Load of trains, 126 tons.

Intervals 15 min., 24 hours per day, 300 days per year; trains per year, 28,800; tons per year, 3,628,800. On a ruling gradient of 80 ft. and maximum of 152 ft., the capacity of the road would be 2,619,-200 tons.

These are very satisfactory results, but some of the advocates of narrow gauge claim for such roads a carrying capacity of 10,000,000 of tons of paying freight and assume data to figure this amount, but they ignore the fact, that grades influence the size of trains,and the carrying capacity of the road.

COMPRESSED AIR ENGINES.

From "Engineering."

It may be remembered that in a former article, we advocated a low piston speed for compressed air engines on the score that by the adoption of such moderate speeds a greater facility is afforded for imparting heat to the air during its expansion, and we further recommended, as a convenient mode of imparting this heat, the immersion of the cylinders and of the main air reservoir in a hot-water jacket. At the risk of some slight repetition, it may be desirable, perhaps, that we should briefly state here the way in which the absorption of heat takes place in a compressed air engine. We will suppose the engine to be of that class in which the air stored up at a high pressure in a main reservoir is allowed to flow thence through a reducing valve into an intermediate chamber, whence it is supplied to the cylinders. If the air is worked expansively in the cylinders, as it ought to be, the absorption of heat during each stroke may be divided into two distinct stages. In the first place, while the admission port is open the piston will be urged forward by the direct flow of air from the intermediate chamber, or, in other words, by the expansion of the air in the main reservoir; while after the cut-off takes place the work will be done by the further expansion of the portion of the air shut into the cylinder, and the expansion of the air in the main reservoir (supposing the latter to be supplying one cylinder only) will cease. The expansion, whether in the main reservoir or in the cylinder, will, unless heat be derived from external sources, be accompanied by a reduction of temperature of the air, and it is this reduction of temperature beyond a certain point which it is desirable to avoid, in order to do away with the trouble attendant upon the freezing of the moisture which the air contains. As we pointed out in our former article, one mode of preventing the attainment by the air of a very low final temperature would be to impart to it a high temperature in the main reservoir, so that, even after expansion, the temperature might not be so low as to allow of the freezing of the vapor ; but, as we then stated, this mode of procedure is open to important practical objections, and it appears to be altogether the best plan to supply the air with heat at the time when the expansion renders that heat necessary. In other words, we believe it to be the best plan to apply heat to both the main reservoir and the cylinders, and we do not at present see a more convenient mode of applying that heat than by a simple hot-water jacket. The intermediate chamber may or may not be included in the jacket, as may be most convenient, there being no absolute necessity that heat should be applied to it, as in passing through it the air does no work.

These preliminary matters being stated, we may proceed to the special object of this article, namely, to show the quantity of compressed air which is required to perform a certain amount of work, and the quantity of heat which it is necessary to supply to avoid the freezing of the moisture. The best way of dealing with these points will probably be by considering a particular example, and we shall therefore suppose a case in which a load of 6 tons, including the weight of the machinery, has to be drawn at a speed of 8 miles per hour over a line 4 miles in length, of which 3 miles are level, while the 4th mile rises with a continuous gradient of 1 in 56. Further we will suppose the line to be a tramway laid through the streets, and that in consequence of the dirt, etc., on the rails, the resistances at the speed above mentioned reach 20 lbs. per ton. In this instance the tractive force required on the level portion of the line will be $6 \times 20 = 120$ lbs.; while on the gradient it will be $120 + \frac{2240 \times 6}{56} = 360$ lbs., or 3 times the tractive force required on the level. Let us further suppose the driving wheels to be 3 ft. 6 in. diameter, and the two cylinders to be $4\frac{1}{2}$ in. diameter with 12 in. stroke, the connecting rods being coupled direct to driving axle. The circumference of a 3 ft. 6 in. wheel is 11 ft. almost exactly, and with the above-mentioned proportions the piston speed when the vehicle was moving at 8 miles per hour would be $\frac{5280 \times 8 \times 2}{11 \times 60} = 128$ ft. per min., a very moderate speed, suitable for the ready absorption of heat by the air during its expansion in the cylinder.

When ascending the gradient of 1 in 56, the tractive force required being 360 lbs., and the wheels and cylinders being of the dimensions already given, the mean effective pressure on each piston would have to be:

$$\frac{360 \times (3.5 \times 3.1416)}{1 \times 4} = \frac{360 \times 11}{4} = 990 \text{ lbs.}$$

while on the level portion of the line 1-3d this pressure, or 330 lbs. only, would be necessary. In such an engine as that of which we are speaking, the mean losses due to back pressure, pre-exhaust, compression, and wire-drawing at the point of cut-off, etc., may be estimated fairly as equal to a mean back pressure of about 9 lbs. per sq. in. above the pressure of the atmosphere, or, say, a total mean back pressure 24.7 lbs. per sq. in. measured above a vacuum. If now we decide upon the ratio of expansion, the quantity of air used and the initial pressure necessary can be readily calculated.

If air was capable of absorbing heat rapidly from surrounding objects it might be possible to carry out the expansion in the cylinder to a very considerable extent without much inconvenience, although even in such a case it might rather be desirable, on account of the difficulty of keeping pistons and stuffing-boxes thoroughly air-tight, to avoid the use of very high initial pressures. As it is, however, there is another reason for keeping the amount of expansion within moderate limits, and this is the comparatively slow rate at which the expanding air is capable of absorbing heat from the surfaces with which it is in contact. Taking this fact into consideration we believe that a fourfold expansion in the cylinder will in most cases be found as great as is desirable; and assuming this to be the degree of expansion decided upon for the engine forming our example, when working on a level, we may proceed to calculate the initial pressure necessary. The diameter of the pistons being $4\frac{1}{2}$ in., the area will be 15.9 in., and the mean effective pressure required on each piston being 330 lbs., the mean effective pressure per sq. in. will be $\frac{330}{15.9} = 20.75$ lbs., which, added to 24.7 lbs., the mean total back pressure, gives 45.45 lbs. as the average *total* pressure required on the piston during the stroke. With a fourfold expansion the mean total pressure is equal, as is well known, to:

$$\frac{\text{initial pressure} \times (1 + \text{hyp. log. } 4)}{4},$$

or if, as in the present instance, the mean total pressure be given, the initial pressure =

$$\frac{\text{mean total pressure} \times 4}{1 + \text{hyp. log. } 4} = \frac{45.45 \times 4}{1 + 1.386} = \frac{81.8}{2.386} = 76.1,$$

or, say, 76 lbs. per sq. in. total, or 61.3 lbs. above the atmosphere. At the same time the final pressure after expansion will be $\frac{45.45}{2.386} = 19$ lbs. total.

When working up the gradient the main effective pressure required in the cylinders would be $\frac{990}{15.9} = 62.26$ lbs. per sq. in., which added to the back pressure as before gives $62.26 + 24.7 = 86.96$ lbs. per sq. in. as the average total pressure on the piston. With such a high mean pressure it would be far from desirable to resort to any great degree of expansion, and when working on the gradient it would probably be found preferable to make the cut-off no earlier than is desirable for the purpose of insuring a free exhaust. Thus a cut-off at three-fourths of the stroke might probably be adopted with advantage, and as in this case the expansion would be $1\frac{1}{3}$ times, the total initial pressure required would be $\frac{86.96 \times 1.33}{1 + \text{hyp. log. } 1\frac{1}{3}}$ $= \frac{115.95}{1.288} = 90$ lbs. per sq. in., or 75.3 lbs. per sq. in. above the atmosphere. In this case the final pressure would be $\frac{86.96}{1.288}$ $=67.5$ lbs. total.

These matters being disposed of, we are now in a position to calculate the quantity of air required for the trip. The driving wheels being 11 ft. in circumference, they will make $\frac{5280}{11}=480$ revolutions per mile, and if we suppose the amount of compression be just sufficient to fill the clearance spaces, there will be thus used for each mile run $480 \times 4 = 1920$ cylinders full of air at the final pressure. The diameter of the cylinders being $4\frac{1}{2}$ in., and the stroke 12 in., the capacity is 0.1104 cubic ft., and during the run of 3 miles on the level there will thus be used $0.1104 \times 1920 \times 3 = 635.8$, or, say, 636 cubic ft. at the final pressure of 19 lbs. above a vacuum; while on the gradient the quantity used will be $0.1104 \times 1920 = 211.96$, or, say, 212 cub. ft. of the final pressure of 67.5lbs. total.

If now we suppose the temperature at which the air is exhausted to be 40 deg. Fahr.,* the weight per cubic ft. at the final total pressures of 19 lbs. and 67.5 lbs. will be 0.1004 lb. and 0.357 lb. respectively. The weight of air used in making the run of 3 miles on the level will thus be $0.1004 \times 636 = 63.854$, or, say, 64 lbs.; while the weight used on the gradient will be $0.357 \times 212 = 75.684$, or, say, 76 lbs. The total weight used on the trip will thus be 140 lbs. The capacity of main reservoir necessary to supply this quantity of air will of course depend upon the initial pressure given to the latter, and we may mention here that the higher that initial pressure is, the less will be the gross weight of the air necessary at the commencement of the trip in proportion to that utilized. Thus, for instance, if it is necessary that the pressure of the air in the reservoir shall never fall below 100 lbs, per sq. in. total, and if the initial pressure be but 200 lbs. per sq. in., then it follows that but one-half of the air originally stored in the reservoir can be turned to account. If, on the other hand, the initial pressure be 300 lbs. per sq. in., then two-thirds of the gross quantity of air can be utilized, and so on, it being supposed that the temperature of the air is maintained constant during expansion by heat supplied from an external source. In the case of our example we will suppose the air to be stored at the initial pressure of 300 lbs. total, and the pressure at the end of the trip never to fall below 100 lbs. total, under which circumstances it will be necessary that the reservoir should contain at starting at least $\frac{140 \times 3}{2} = 210$ lbs. of air. At a pressure of 300 lbs. total, and a temperature of 62 deg., air weighs about 1,552 lbs. per cubic ft., and the capacity of the reservoir would have to be at least $\frac{210}{1.552} =$ 137 cubic ft. To guard against losses by leakage, etc., it would, however, be necessary to provide perhaps about 20 per cent. greater capacity than this, or say 170 cubic ft., in which case a reservoir of the requisite size might be of 34 lengths of wrought-iron tubing, each 10 ft. long by $9\frac{5}{8}$ in. diameter inside.

We now come to the final question which has to be considered here, namely, what is the amount of heat which it will be requisite to supply to the air to compensate for that rendered latent during expansion? In dealing with the question we shall for the present neglect the slight difference between the initial and final temperatures (namely 62—40=22 deg.), and shall suppose the reduction of pressure to be caused by increase of volume only. If the *absolute* temperature (that is to say the temperature in degrees Fahrenheit+461.2) of any quantity of air at a given volume V_1 be represented by T_1, then the absolute temperature, T_2, of this quantity of air when expanded to the volume V_2, will be $T_2 = T_1 \times \left(\frac{V_1}{V_2}\right)^{0.408}$. When the engine taken as our example is running on a level, the air is discharged at a total pressure of 19 lbs., while the pressure in the reservoir is 300 lbs., and the relative volumes on the supposition already stated would be as $\frac{300}{19}$:

* In dealing with the pressures in the cylinders, it was assumed that the air was maintained at a constant temperature, and it may at first sight be deemed that this is inconsistent with the air being exhausted at a temperature of 40 deg., while the initial temperature in the reservoir is taken subsequently at 62 deg. In reality, however, there is no such inconsistency, as the reduction of temperature from 62 deg. to 40 deg. may take place between the reservoir and the cylinder, and it is, in fact, to a certain extent, preferable that it should take place at that point, as the lower the temperature in the cylinder the greater is the facility afforded for the transmission of heat to the air from external sources.

1=15.7 : 1. The initial temperature being 62 deg. Fahr., or 461.2+62=523.2 deg. absolute, the final temperature would, if no heat was supplied from an external source, be by the formula just given : $T_2 = 523.2 \times \left(\frac{1}{15.7}\right)^{0.408}$. The 0.408th power can be readily calculated by the aid of a table of logarithms, and we then have $T_2 = 523.2 \times \frac{1}{3.076} = \frac{523.2}{3.076}$ 170 deg., as the final absolute temperature. The fall in temperature would thus be 523.2—170=353.2, or, say, 353 deg., and in order that the air might be exhausted at the same temperature at which it left the reservoir it would be necessary to supply to it from external sources as much heat as would raise the temperature of the weight of air passing through the cylinders 353 deg.

We have, however, supposed the exhaust to take place at 40 deg., or 22 deg. below the initial temperature, and the heat to be supplied from the hot water jacket, or other source, while the engine is running on the level, will only be that requisite to raise the weight of air used 353—22=331 deg. The weight of air used in passing over the level portion of the line being 64 lbs., and the specific heat of air being 0.238, the heat required for this portion of the trip will be 331 deg.× 64×0.238=5042 pound-degrees.

Proceeding in the same way for the portion of the run made on the gradient, we find the relation between the initial and the final volumes to be $\frac{300}{67.5}$: 1, or 4.44 to 1; and the temperature, T_2, thus becomes $523.2 \times \left(\frac{1}{4.4}\right)^{0.408} = 523.2 \times \frac{1}{2.073} =$ 252.3 deg.; and the fall of temperature, supposing no heat to be supplied, would thus be 523.2—252.3 =270.9 or 271 deg. Deducting, as before, 22 deg. for the lower temperature of discharge, we find the amount of heat required when the engine is mounting the gradient to be that necessary to raise the quantity of air used 271—22=249 deg. The weight of air used on the gradient being 76 lbs., the heat required will be 249×76×0.238=4504 pound-degrees.

The total quantity of heat to be supplied to the air from the hot-water jacket throughout the whole trip is thus 5042 +4504=9546 pound-degrees, and, if we suppose the water to be allowed to fall in temperature but 30 deg. only—say, from 200 deg. to 170 deg.—the quantity of water which it would be necessary to carry in the jacket would be but 318.2 lbs., or, say, 32 gallons. In order to allow for imperfect circulation, the quantity requisite in practice would have to be greater than this; but in all probability a supply of 50 gallons at an initial temperature of 200 deg. would be ample to insure the maintenance of the requisite temperature of the air throughout the trip.

The present article has extended to such a length that we have no space to speak of the mechanical details to which it would be requisite to give attention in carrying out the mode of working compressed air engines which we have been describing. These points, however, we may possibly touch upon on some future occasion. Meanwhile we may state that it must be borne in mind that the employment of compressed air for working an engine cannot be regarded as an economical mode of utilizing power, as an important loss of effect will in all cases ensue, from its being at present practically impossible to turn to account the heat generated while the air is undergoing compression. Notwithstanding this, compressed air affords a means of transferring power which is capable of doing good service in many situations, and it is therefore well worthy of the attention necessary to ascertain the best mode of turning it to account.

Nickel Mines.—Attention is being called to the nickel mines of the country, which promise handsome returns for their development. The only such mine at present practically worked is in Eastern Pennsylvania, and is highly remunerative. In Missouri, one mine was worked from 1850 to 1855 on the Mine-la-Motte tract. The ore was the sulphuret, associated with lead and copper. About $100,000 of nickel was realized from mining the croppings of this vein. "Outcrops" of this ore are also found in Madison, Iron and Wayne Counties, Mo., but none are worked at present, as we are informed. The refined metal is worth about $3 per lb., and for many purposes supplants silver.

THE CAUSES OF EARTHQUAKES.

(*Continued from page* 544.)

6.—HOW THE EARTHQUAKES ARE PRODUCED.

Let us take it for granted that, owing to the living activities of the earth, a considerable quantity of these necessary chemical elements have collected, and that the waters of the sea having percolated and saturated them, a very active chemical action has taken place and evolved a considerable amount of calorific.

This will soon reach the incandescence, particularly if the point where the chemical action is taking place happens to be in contact with the voltaic arch formed by the electro-magnetic current passing between the sun as positive element and the earth as negative. This is precisely what has occurred on the 13th of August, 1868, in the southern provinces of Peru, and three days later in the northern of Ecuador.

It is a fact worthy to be noted, that the great and destructive earthquakes have always taken place at the time of some eclipse of the sun or moon.

The moment a single atom becomes incandescent, irradiation takes place, and the surrounding atoms soon attain the same degree of heat as the first, the inciting causes being incessantly at work. From this focus of irradiation, caloric will extend from one molecule to another ; and it will not be long before a large subterranean furnace will be in existence.

What will then happen ? It is perfectly obvious that the water existing in the neighborhood will be converted into steam, and this constantly overheated into gases, which by their enormous dilatation will exert a tremendous pressure against the wall of their place of confinement.

Everybody is now acquainted with the force of expansion of gases. In their action on the superficial strata we shall find the explanation of earthquakes.

These gases must find an issue. They press against the crust above in a perpendicular direction. This crust happens to be sufficiently resistant, composed of homogeneous materials that render it elastic—upheavals then take place, like those observed from the remotest antiquity to our times. All these upheavals are always preceded by earthquakes, with emissions of sulphurous vapors and sulphuretted hydrogen gas, smoke, etc.

If the crust is not sufficiently resistant, a new crater is opened, a volcano is formed. These are the boils on our mother earth's body, that having ejected all the matter contained in them, subside and even disappear. We have an example of this phenomenon a few miles from Granada (Nicaragua) in the volcano of Musalla, which has completely vanished since the conquest by the Spaniards, and the place where it stood is now a level plain covered with burned and blackened stones.

Let us suppose that the superstrata are homogeneous, and so resistant as to withstand the enormous pressure of the immensely dilated gases. Then the soil will be convulsed, tremendously shaken ; and the mighty works of men destroyed, leveled to the ground.

As deep as man has penetrated in the superficial strata of the planet, he has found them honeycombed; traversed in all directions by moats, conduits, caverns and hollows, which contain large deposits of water, forming lakes and pools, originating subterranean currents, streams and rivers.

These moats, conduits, caverns, etc., etc., are separated by walls more or less thick. These walls in the vicinity of the furnace, being less resistant than the crust above, give way under the pressure of the gases; an issue is opened for their escape. They precipitate themselves into it with incommensurable force ; hence the rumbling noise—the thunder-like explosions which always accompany earthquakes and precede them by a few seconds, giving warning of their coming.

By the falling of the walls of the caverns and moats, the props of superstrata being destroyed, these cave in; hence the abasements of the surface, the rendings, the disappearance of some streams, the appearance of others—the changes that take place in the configuration of the countries where the catastrophe has occurred.

The gases, in their onward rush, meet other openings ; part precipitates into them. Soon they expand on a larger field; their forces, not being any longer concentrated, grow less and less as they find more avenues through which to escape; and as they are further from the centre of their generation, that is to say, from the furnace. Many of these furnaces, no doubt, exist, that having communications with active volcanoes are not perceived on the surface; or have a vent in the shape of Geysers, hot springs, mud volcanoes, etc., etc. The hot well discovered at Lacrosse, Wis., in the month of February, 1868, when some men were boring an artesian well, bears witness of the truth of my assertion.

The upward pressure against the ceiling of the conduits, accounts for the waters in the wells overflowing, and for the changes of their level. The sulphurous nature of the gases accounts for the fetidity observed in subterranean waters, in caves and cellars.

Different and very distinct motions of the soil have been noticed during earthquakes. They are easily accounted for.

The most common is known under the name of *undulating motion.* It may be explained in this wise.

The walls and ceilings of the subterranean cavities are rugged and uneven, resembling somewhat the waves of the ocean during a gale, with more or less deep indentations; they are not composed of the same and homogeneous materials. In places they are more resistant than in others; and when gases come from a long distance, and somewhat disperse, they do not exert their power with so much force on the ceilings. They consequently give rise to a motion similar to that felt on board of a vessel at sea, and called for this reason *undulating motion.*

There is a second motion called *sussultaria,* eruptive. This has been observed many times, and always accompanied by great catastrophe.

Such motion, foreshadowed by sulphurous vapors, occurred during the months of February and March, 1783, in the plains of Calabria and Mesina, when the tops of granite hills were clearly seen to jump up; the stone foundations of houses, even the pavement in the streets, were so lifted up as to be found turned upside down.

The city of Riobamba was destroyed by one of these eruptive motions in the year 1797, and the bodies of some of the inhabitants thrown on the top of a hill 100 ft. high.

Palmeri and Scachi, in their report on the earthquake of Melfi, which occurred the 4th of August, 1851, expressly say, that columns were broken at the base without losing their perpendicular position; that chimneys were heaved up into the air, falling again in their natural place.

The city of Mendoza was destroyed in 1861 by a motion of that kind.

The ceilings of the furnace, being homogeneous and resistant, will not swell or upheave, but sustain the shock occasioned by the puff of the gases incessantly arising, dilated from the focus of heat, in the same manner as the steam escaping at intervals through the escape pipe. The perpendicular shock is repercussed to the surface, in the same manner as if you give a sharp blow under a table; the table, to be sure, will resist, but the objects on it will be thrown up into the air.

The third motion (moto vorticoso) is rotary or circular. Many doubt its existence; but I see nothing that can be opposed to it. We read in the papers an account of the earthquake that was felt in the year 1868 in San Francisco, California, and a motion of that kind is said to have been observed in the lower part of the city.

After the earthquake that occurred in Valparaiso in 1822, three palm-trees, placed at a short distance from each other were found intertwined, and so have remained ever since.

It is also reported that after the earthquake of 1783 in Calabria, two square obelisks placed in front of the Convent of St. Stephano del Bosco, were found turned round on their pedestals. Many other cases, similar to those, are reported, proving the existence of the rotary motion.

But, how is such motion to be explained?

In two different manners. Have you ever noticed how a rotary motion can be imparted to a small metallic wheel, supported on a steel or iron axle, on which it can revolve freely, merely by rubbing vigorously with a rough file one end of the axle? If so, you have seen it turn of itself as it were in the same direction as the file is drawn.

Why would not also a powerful stream of gases, rubbing against the rugged ceilings of the conduits, produce a strong electro-magnetic current, that would impart a rotary motion to the objects on the surface, in accordance with the laws that govern currents of induction.

Again, this rotary motion may be explained in this wise.

When two currents of air, coming from opposite directions, meet each other, they give rise to a whirlwind. If these currents are very strong, a hurricane or tornado is the result. Well, there is no reason why the same phenomenon, which takes place above ground, should not also occur under ground, when two different current of gases, coming from opposite directions, meet in the interterrestrial passages and cavities.

Nature works in the same manner in all its manifestations when the conditions are equal. Similar causes produce like effects; then two currents of gases meeting under ground, will produce a tornado; and a rotary motion will be imparted to all objects within its boundaries.

I have reviewed in a very cursory manner all the effects produced by the convulsions of the earth, and, by the synthetic method of reasoning, tried to arrive at the understanding of their causes. I have not advanced an opinion, which is not founded on *facts* acknowledged by science, on events recorded in history. I do not propose any theory, but merely give in these few lines the result of my own observations and investigations. If they satisfy your mind, as they do mine, then I am happy, for I have attained the object I had in view when I took the pen.

Let me then recapitulate, and sum up in a few words my

7.—CONCLUSIONS.

1. There is no central fire. It is unphilosophical, unscientific to uphold the opposite doctrine—for it merely rests on speculations, unsupported by facts and science. It must therefore be disregarded by all scientific minds.

2. The heat of the earth has its source: 1st. In the friction occasioned by its rapid motion through the cosmic matter that fills all space. 2d. In the rays of the sun, that, however cold in themselves, carry light that, setting in motion the molecules of the atmosphere, generates heat, which is communicated to the earth. 3d. In the constant chemical decompositions that are incessantly going on in its great interior laboratories. 4th. In the oxidation of the metallic substances that compose the superficial strata of the planet. All these phenomena are produced by the agency of electro-magnetism, which seems to be the life sustainer of the whole creation.

3. The volcanoes are not the safety valves or vents of a central fire, which does not exist; but are merely local accidents produced by a conglomeration of materials, sulphur being one of the principal, that, being soaked by salted waters, enter into chemical decomposition, under the agency of electro-magnetism, and that the volcanoes are to the surface of the earth what boils are to the surface of the human body, which disappear as soon as the matter accumulated is expelled.

4. That the sun's immense reservoir of electro-magnetism, and the other celestial bodies, which are likewise reservoirs of the same agent, increases the action of the electro-magnetic currents that traverse the earth, according to their respective positions with regard to this, and hasten the effect of the chemical operations, if a point of the voltaic arch formed by them comes in direct contact with the place they are going on on a large scale.

5. That earthquakes and volcanoes stand in intimate relations, have a common origin, and will ever occur in those places where large chemical action is taking place. That inasmuch as chemical action is alive in every part of the earth, earthquakes may be felt on any point of its surface.

6. That the origin of earthquakes may be found in the expansion of gases generated by the various causes enumerated, particularly chemical decompositions. These gases, being prodigiously dilated, press heavily against the wall and ceilings of the cavities in which they are confined, and in trying to find an issue through which to escape, produce the dreaded phenomenon.

7. That when a volcanic action is going on in the substrata of the surface of the earth, and earthquakes are impending, the phenomenon is foreshadowed by many precursory signs.

8. That among these forerunners the following are the most evident: 1st, sulphurous vapors arising from the ground in the vicinity of the focus of the chemical action; 2d, strange and mysterious noises,

produced by the activity of the gases; 3d, alterations of the mineral waters, occasioned by the percolation of the gases through the porousness of the superficial strata, and affecting its chemical compounds; 4th, turbidity of the fresh waters in wells—phenomenon produced by the same causes; 5th, changes in the level of the waters in wells, caused by imperceptible upheaves and depressions of the superficial strata, affecting the sources or subterranean streams which feed them; 6th, emanations of carbonic acid or sulphuretted hydrogen gas, perceived in cellars, caves, wells, excavations; 7th, electro-magnetic disturbances in the atmosphere, suddenly taking place and without any apparent causes, manifested by the loss of power of magnets.

10. That the opinion of Plinius, the elder, commends itself to the serious consideration of all men of science: that the evil consequences of earthquakes might in some measure be arrested by boring deep artesian wells in the countries subject to earthquakes, for those wells would act as vents through which the gases might escape, and their raging storm partly quelled.

A few years ago, 4 deep wells were discovered, one at each corner of the cathedral in Lima, which had been destroyed by the earthquake that laid that city to the ground in 1687. The church was rebuilt and these wells bored to act as protectors of the monument. They have well fulfilled their duty, for the edifice has withstood all the different shocks that since that epoch have visited the capital of Peru, and destroyed many of its strongest structures.

8.—CATACLYSMS OF THE 13TH AND 16TH OF AUGUST, 1868.

These cataclysms are some of the most terrible known in the history of mankind, as much for the ravages they have occasioned, as for their duration and the extent of country they have visited, spreading dismay and consternation, death and ruin among the inhabitants. Beautiful and densely populated cities have been levelled to the ground, flourishing seaports swallowed by the sea, whole towns together with their dwellers have disappeared into the bowels of the earth.

In Peru the shock was felt over a radius of 1,670 miles. In Ecuador, 43,000 human lives were destroyed in a twinkling of the eye.

The centre of the earthquake of the 13th appears to have been the volcanic zone comprised between Arequipa, Tacna, and Moquegua, where are situated six volcanoes—the *Cailloma*, the *Misti*, the *Ubinas*, the *Huaina-putina*, which made an eruption on the 13th of February, 1600; the *Tutupaca* and the *Candarare.*

The focus of the second, that of the 16th, in Ecuador, was in the volcanic fields of Ocampo, surrounded by the 3 volcanoes, the *Cotacachi*, the *Imbabura*, the *Pasto.*

The prefect of Arequipa, Dr. Francisco Chocano, in his report to the Secretary of State, says: That on the 13th of August, at 5.15 P. M., a very severe shock of earthquake was felt in Arequipa, when within 5 minutes the whole city was levelled to the ground. The oscillations, from S. to N. E., shook the soil with tremendous violence during 7 minutes; they came accompanied by *gushes of air charged with electricity*; the motion of the earth was such as to make it next to impossible to keep a firm footing or remain standing. *The soil heaved up and fell as the surface of the sea during a gale. A sudden obscurity spread over the city, adding* to the horrors of the event. *The waters became muddy in an instant.* During the night of the 13th, 35 shocks were counted, but the soil was in continuous motion. *Loud detonations were heard every instant and in rapid succession,* like the rattling of musketry during a battle. *Rents were opened in the earth; sources sprang forth through them* so abundant as to inundate many places; others have sunk and disappeared. The shocks continued at intervals. The Misti *sent forth enormous columns of smoke* in the midst of horrid detonations.

Such were the events of that memorable afternoon of August 13, 1868, that were witnessed by the inhabitants of Arequipa.

All these phenomena I have reviewed and tried to explain are effects of volcanic action. Arequipa is built on the slope, nay, at the very foot of the Misti, and has at periods nearly equidistant been destroyed.

On the 2d of January, 1582, an extremely severe earthquake shook that city to its very foundations; another, equally terrific, occurred in 1587; then another, in 1590, that laid to the ground the city of Camaria, an immense tide wave invading the ground, inundating the Peruvian shores; again, on the 18th of January, 1600, when the volcano Huayna-putina made an eruption; again, on the 25th of November, 1601; again, in 1605, when the city of Arica was destroyed; again, on the 13th of May, 1647—the shock was that time felt along the whole coast; again, on the 22d of August, 1715; again, on the 6th of February, 1716—day of the destruction of the city of Torata; again, on the 27th of March, 1725—this earthquake shook the whole southern coast, and the port of Callao was submerged by the sea; again, on the 13th of May, 1784. I merely mention these earthquakes as they are the most important, passing in silence hundreds of others of minor intensity, that at short intervals have occurred, warning the inhabitants of these regions, that under their feet was a focus of electro-chemical action, whose living activity continually threatened their existence.

Commandant Thomas Layseca, of the forces stationed at Torata, informs us that the earthquake was felt at 5 P.M., lasted 12 min.; and that from the 13th to the 15th, date of his official report, 600 shocks had taken place.

In Tacna, on the 13th of August, a *grand oscillatory motion* of the earth occurred at 5 P.M., lasting 5 min. At that place, for several days previous to the 13th, *subterranean noises were heard, and some light shocks felt.* When the earthquake occurred the day was cloudy, and shortly after it began to rain (a strange phenomenon in a country where it never rains), to the 16th of Aug., that is, during three days 64 vibrations, accompanied with subterranean noises, were felt; large and deep rents opened on the surface, and gushing through the openings. In Palea and La Portada, on the road to Bolivia, the shocks were most violent. *Large portions of hills became attached,* and rolled down the valleys— *the mountains being split open with frightful noise.*

I will call your attention to the fact, that in this place the motion of the earth was different from that at Arequipa, being *oscillatory*, instead of *undulating*, as it was at the latter place; notwithstanding its violence at both places, being such that men could scarcely keep their footing, the results were quite different. The strongly stone-built city of Arequipa was levelled to the ground, while in Tacna only 40 houses were destroyed.

This fact would tend to show that the oscillatory motion causes less ravages than the undulating.

Again, the premonitory symptoms of the impending catastrophe were distinct, but passed unheeded.

Electro-magnetic disturbances took place also in the atmosphere, causing rain to fall—an occurrence which seldom or ever takes place in this part of the country.

In Chocorento, a village in the valley of Acari, the earthquake took place at 4.30, destroying all the houses in the valley. The shocks succeeded each other in rapid succession; the sea rose mountain high, and ran inland one and a half miles; all the watercourses became dry; the ground opened in many places, and *water gushed up* through the fissures in large bubbles; *continuous noises*, resembling the roaring of cannons in a battle-field, were heard incessantly.

It would seem that the phenomenon manifested itself at this place 30 min. in advance of the other localities; but this is evidently an error of computation of time on the part of the observer; for this valley is in close proximity to the other places.

In *Moquequa*, the earth began to shake at 4.45 P.M., five minutes in advance of Arequipa and Arica, about 90 miles to the southwest of the former city. There the vibrations were always preceded by *electric discharges*, louder than the heaviest cannonading; were from east to west, alternating with *vertical shocks*, and succeeded each other with frightful rapidity during 5 to 6 min. The hills of limestone were split, the rocks rent in small pieces. The soil opened, and through the openings issued streams of *blackish and pestiferous water.*

With *Arequipa* and *Moquequa*, the city of Arica is that which has suffered the most. Situated on the sea-coast 40 miles to the southwest of Tacno, it is the most important port of Peru, next to Callao.

At 5 P.M., a very severe earthquake was felt on shore, says the commandant of the ill-fated frigate America, which was stranded that day. "All the houses in the city surged, and with an ominous crash fell to pieces; then the earth was seen to open, a *rolling, rumbling noise* was heard, *and gases, stifling gases,* emanating from the fissures, soon filled the atmosphere, severely oppressing all living creatures, causing them a sensation of suffocation. The shocks lasted 10 min., and succeeded each other at short intervals, and were accompanied with subterranean explosions. The hills themselves were seen to stagger like intoxicated beings. Large boulders, detached from their brows, rolled down their slopes, while their sides were seen to give up the dead bodies of the Aymarcis, that for centuries had been intrusted to their safe keeping, and had so long peacefully slept in their solitary resting-place, the slumber of death. These mummies seemed to have emerged from their graves, as if to witness the convulsions of mother earth ; and their lifeless mouths appeared to laugh, exhibiting gumless rows of white teeth, at the terror of the living seeking refuge in open places, and flying to the top of the high lands for their lives.

The shocks came from the south ; the skies were stormy, a very light wind blew from a southerly direction. The whole soil of the country, as far as it could be seen, was moving ; first like a wave, from north to south, then it trembled, and at last upheaved heavily.

During that time a very *strong current from the south set in* in the bay. The current was so strong as to set adrift the boat of the frigate America, sent to shore for the commandant, notwithstanding the efforts of the crew. It measured $5\frac{1}{2}$ miles an hour, lasted 5 min. Then came a *second current* from the opposite direction; this left the bay nearly dry.

Currents, now from the north, then from the south, succeeded each other with great frequency, and became so rapid as to make it impossible to send boats to rescue the people who were seen floating on the palisade and imploring help. The frigate began to drag her chains and anchors. At 6.45 P.M. the currents increased to $9\frac{1}{2}$ miles, their duration being from 5 to 10 min. ; at 7.5 P.M. a current came from the south, its rate $10\frac{1}{2}$ miles. Then the sea began to retire slowly from the shores, leaving the boats dry. It receded about to the line of extreme low tide, when at once it rose again and invaded the land. It reached a height of 34 ft. above high-water mark, overflowed the town, and destroyed everything that the earthquake had left standing. The waters rushed back in the ocean, and rose again to the same height as before. Several times did the advancing waves wash over the doomed city ; several times the force of the waters carried all the debris of the ruined habitations of men, until at last, retreating about 2 *miles*, it returned as an immense wave 50 ft. high, carrying the frigate America more than a mile beyond the railway tract, in a place called *Chinchero*, and the American ship Wateree about a mile further up the beach.

Eleven tidal waves occurred, the intervening time between each invasive wave was 3 min., the third invasion having occurred soon after the first; and the last and largest 20 min. after the first.

At Iquique the earthquake lasted 5 min., the sea rose 30 ft. above its ordinary high-water mark, and covered the town to the extension of 600 ft.

At Ilo, north of Arica, the sea retired, leaving the ships completely dry, and rising again in a wave 40 ft. high washed away all the houses and everything else.

At Islay the waves obtained also an altitude of 40 ft. over their natural level, and covered 3 times the wharf without doing much injury. The town, being built on the summit of a very high cliff, escaped destruction.

Caracas, a small landing place near Jisco, was swallowed by the sea, and the boats that were in the bay carried away and left two miles inland.

In Callao the earthquake was felt at 4.46 P. M.. It came with an *oscillatory motion*—a motion similar to that of a boat in calm weather; it lasted 10 min.; at 6.30 P. M. another shock was felt, of 5 min. duration. A few minutes before 7, high-water was to take place. The water, instead, began to recede; at 10.30, for the first time, the water reached a higher level than it was ever known to have attained before, within the memory of man; at 11 a tremendous wave, 18 ft. high, invaded the land to upward of 600 ft. from the beach; currents set in from opposite directions at a velocity of 3 to 4 miles an hour; at the time a soft breeze from S.W. blew, the atmosphere was perfectly clear.

These are, in as few words as possible, the phenomena that were noticed during the terrible cataclysm of the 13th of August, 1868; the greatest, perhaps, on record, with that of the 16th of the same month, which visited the province of Imbabura during our historical period.

Following the great tidal wave which originated on the coast of Peru, on its way across the Pacific, and taking into account that the difference in longitude between Arica and New Zealand is approximatively 9 hours, we shall find that the wave having reached the New Zealand coast at 6 A. M. of the 15th has employed 29 hours to travel 6,120 miles. Its velocity may, therefore, be computed at 211 miles per hour. Its violence, even then, was extraordinary. The Island of Chatham to the eastward suffered greatly, for the wave that struck it was of such magnitude as to completely destroy the colony of Tupinga on the North.

The tidal wave reached Hokodadi (Japan) at 10 A. M. on the 15th, presenting itself by a series of waves that caused the sea to recede and be depressed until 3 P. M. under its level, and rise again above it with great velocity. During 10 min. per watch a difference of 5 ft. was measured; the constant elevation and depression of the tide at that place being only 2½ to 3 ft.

It reached the Sandwich Islands on the 14th at 8.46 P. M., and continued to manifest itself during the 14th, 15th, and 16th, by a series of waves, rising and receding 3 to 4 ft. every 10 min.

From these data a comparative table showing the time employed by the tidal wave to reach the different places may be thus formed:

PLACES.	GREENWICH TIME.			LOCAL TIME.			
	Dates.	H.	M.	Dates.	H.	M.	
Peru	13	9	40	13	5	..	P. M.
Sandwich Islands	14	2	6	14	3	46	A. M.
New Zealand	14	7	6	15	7	..	A. M.
	14	13	6	15	10	30	A. M.

Fifty-six hours after the ruin of Arequipa and other cities of Peru, another terrible cataclysm visited the northern provinces of Ecuador. The volcanic fields of Ocampo seemed to have been the focus of the electro-chemical action whose effects culminated in the destruction of 40,000 human lives, and the ruin of the cities of Otabalo, Ibarra, Atmitaqui, Catacachi, Perucho, San Antonio, San Pablo, and many smaller towns and villages besides part of the city of Quito, the ancient capital of the Seyris, or Kings that governed the Empire of Quito, before its conquest by Huayna-Capac, and the modern capital of the Republic of Ecuador.

Quito, built on the slopes of the volcano Pichincha, is elevated 9,500 ft. above the level of the ocean. Several times it has suffered from the eruptions of the Pichincha since the conquest, the most remarkable being those that occurred in 1575, 1587, and 1660. The cataclysm of the 16th of August seems, however, to have been the most disastrous that has afflicted these regions, the most volcanic known on the globe. Here are found grouped on a plateau about 200 miles long by 80 broad, a great many volcanoes, which, for the most part, at different epochs since the conquest, have given the most unmistakable proofs of activity. The Chimborazo, the Cotopaxi, the Pichincha, the Altar, the Illinaza, the Corazon, the Cayambé, the Riobamba, the Sangai, and many minor ones, are here gathered nearly within sight of each other.

The earthquakes that visite Chili, Peru, Ecuador, and California, withen the five days that elapsed between the 13th and 19th of August, notwithstanding their synchronism, did not originate from the same centre of action. Each had a distinct focus, to which a greater activity was communicated by coming in contact with some of the points of the voltaic arch formed, in those days, by the relative positions of the sun, moon, and earth.

In Quito meteorologic disturbances occurred on the 15th: heavy showers of rain and hail, and heavy thunder; at 1.20 A. M. of the 16th a severe shock of earthquake was felt, then the earth continued to shake at intervals to the 19th. All the principal churches were levelled to the ground.

In the district of Catuchi two towns were totally destroyed without leaving a trace of having existed. The town of Atmitaqui was destroyed; in that of Ibarra, the capital of the province of Imbaburi, 13,000 persons perished; rents were opened and closed, huge pieces of rocks were seen tumbling down the sides of the mountains, hills sank, carrying with them sugar-cane plantations, houses and everything on them. That where the city of Otavalo was built, sank and was replaced by a lake. Where Cotacachi once stood is now as wamp; large quantities of stones were hurled from the Cotacachi; from the Imbaburu issued a torrent of mud, the flow of which was followed by that of water; from the crater of the Ocampo were ejected large quantities of bituminous matter. The Sangai was seen in a state of constant eruption. Dark clouds of dust and a heavy rain of fine powdered earthy matters fell; a total darkness prevailed and covered the country as a pall, the obscurity of which was illuminated at intervals by flashes of light from the volcanoes, amidst continuous detonations that resembled the roaring of a distant cannonading.

Resuming all these data, I came to the conclusion, that the production of these phenomena had its origin in 4 different centres of action. Those felt in Peru had for centre the country between Moquegua, Arequipa and Arica, encircled by the 4 volcanoes—the Misti, at the foot of which is situated Arequipa; the Huayna-putina, the Ubinas, and the Tutapaca, forming part of the chain of Cordilleras immediately behind Moquegua.

2. The earthquakes that shook the greatest part of Chili seems to have originated in the volcano of Leullallco, situated 240 miles from Copiapo. It was reported to have broken out in a violent eruption, its crater vomiting lava, ejecting large stones; the ground at the base of the mountain opened in numerous places, and through the rents spouted forth currents of water impregnated with sulphuretted hydrogen gas; these occurred on the 14th and 15th of August.

3. The earthquakes that destroyed the northern parts of Ecuador had their centres of action in the fields of Ocampo, and in some of the numerous active volcanoes that are strewed all over the great plateau of Quito. They took place on the 16th of August.

4. The earthquake that occurred the 16th of August in San Francisco and various other places in California, had probably their origin among the numerous volcanic fields that are so frequently met with in that country; and their centre of action may have been the same that has produced lately the earthquakes of Sacramento, Inyo, and other places.

THE NEW ZEALAND FLAX.

From "Journal of the Society of Arts."

A report of the Flax Commission, appointed to investigate the preparation and the relative value of the *Phormium* fibre, or New Zealand flax, has ben printed, in which the microscopic structure and chemical composition of this plant, together with its market prices and general use, as compared with Irish flax and Russian and Manilla hemp, are set forth. It appears that there are several flax-mills at work in the colony, varying in their efficiency and the quality of the article produced; but that room yet remains for further improvements to be effected. The first duty undertaken by the commissioners was to visit the chief districts where *Phormium* fibre is prepared, and to inquire into the different processes of manufacture. The tables of the Registrar-General had shown that, during the year 1870, there were 161 mills in operation, with an aggregate of 342 stripping machines, employing 1,450 horse-power, 1,766 persons, the produce being 4,457 tons of fibre; but several proprietors had closed their mills at the time of this commission, in consequence of the fall in the value of the fibre. The inspection by the commissioners, of the mills then actually at work, proved that throughout the colony one almost universal method of manufacture is adopted, with the view of producing fibre for rope-making. The green leaves are stripped by revolving rollers with projecting beaters, travelling at a high rate of speed, which crush the epidermis against a fixed plate so set as to allow room for the fibre to remain intact. The fibre, thus freed from the leaf of the plant, is washed by various methods, put on the ground or on lines to dry and bleach, finished by an arm or barrel-scutch, and when baled is ready for the market. No material alterations in the manufacturing processes have been made, but a more skilled labor and enlarged experience have improved the general quality of the fibre, so that it is more eagerly competed for in the London market, as approaching nearer the appearance of Manilla hemp, and is in fact capable, in the opinion of competent judges, of being so prepared as to surpass it. The chief improvement, recently introduced, is the wet-scutching, by which the fibre is cleaned and softened, although it has not always been commercially successful, for, whilst local purchasers were ready to give £3 per ton extra for the flax, the loss of fibre by formation of an excessive amount of tow, and the additional expense of labor, increased the cost from £6 to £10, so that the new process was abandoned; but, notwithstanding this, the commissioners strongly recommend it for further trial. The mills are chiefly worked by steam power, and good streams of water are also essential for the effectual washing of the fibre, which, when carefully prepared and neatly baled, fetches as much as from £17 to £21 per ton, although the ordinary price is about £15. The cutting of the flax leaves is an important point. In some fields an established vigorous plant, in suitable soil, will yield four good leaves for manufacture every year. The leaves are usually of twelve months' growth, and vary from 3 to 5 ft. long. In some parts they are greatly injured by a small "looper" caterpillar, about an inch in length, which eats quite through the fibre, in patches from a half to two inches, and a quarter of an inch broad. This insect comes to its full size, and is most numerous, in the month of December. Of the leaves, when cut 5½ tons yield one ton of fibre. They are mostly found after two years' growth to have passed their prime, and begun to decay. The green strippings of the leaf form food for the horses. Extensive areas, covered with wild *Phormium* plants, leased from the natives, with abundance of water at hand, and labor at a moderate rate, render some of the mills highly profitable. They, of course, vary in their value, and improved plans of scutching, setting, rolling, and washing, with other important points in the process, are occupying the attention of the manufacturers generally. The commissioners state that more life and enterprise in respect to the fibre industry are to be found in Canterbury than in any other province. An interesting question has been raised as to the relative durability of the *Phormium* fibre rope. It is discovered that the New Zealand white rope, when kept dry, will last longer, and wear 60 per cent. better, than tarred rope of the same material, and 34 per cent. better than Manilla hemp rope, although this last is found to be actually improved when wetted with salt water, in consequence, it is believed, of the shrinkage—equal to 5½ per cent—which takes place, whilst the effect of the salt water on the New Zealand rope reduces its lasting qualities 34 per cent. The *Phormium* rope of Canterbury, when oiled, is proved to possess a great power of resisting wet. Plain New Zealand rope, constantly in the water in a Californian pump, was found to last not more than seven or eight days; Manilla rope would run for twenty days; but a piece of the oiled New Zealand rope did not give way till it had been 95 days in continual wear. For heavy work and running gear, the fibre has been so successfully treated, being divested of the gum and otherwise strengthened, as to become, in the estimation of many, more valuable than Russian or Manilla hemp. From samples carefully collected by the commissioners, the breaking strains of a large portion have been determined, and it is shown that the strength of the several descriptions at present exported varies from 53 to 84, with an average of 69, as compared with Manilla, which is taken as the standard at 100. On the other hand, the samples of native-dressed fibre ranged from 70 to 122, with an average of 91. In the northern and central districts, the quality of the fibre thus tested has been best, but in the south there is a marked absence now of those inferior qualities which once created an unfavorable impression in the home markets. There has been a classification of fibres, according to the manner in which they are cleaned and freed from scull, and also in reference to their color and texture. Such terms as "mixed in color," "harsh," "wiry," "poor color," "green and brown," "red ends," "croppy," "coarse," "rough," "much straw," and "heeled," are of frequent use, and indicate differences in value to the extent of several pounds sterling per ton. It is also mentioned that the sisal fibre, which is obtained in Yucatan from a species of aloe, is the only kind that will compete with the *Phormium* as a substitute for Manilla. The native-dressed *Phormium* appears to be the finest, but it has been found almost impossible to obtain any large supply of it. It may be interesting to add, that there are several kinds of this peculiar fibre, differing chiefly in their color, especially of the edges and mid-rib, and that the growth of the plant in its earlier stages is exceeding slow. It is, moreover, found that the varieties are most surely perpetuated by sub-dividing the roots. The structure and mode of growth of these roots show that a true under-ground stem is formed with fibrous rootlets, which stem, after a growth of several years, with a succession of leaves, bears a flower stalk, and then decays; but it also, during the period of its growth, gives off lateral buds, from which new fans proceed, acquire their own roots, and finally become independent plants, clustering together, and forming unusually large bushes. In propagating the plant, these lateral fans, as soon as rootlets have been formed, may be removed and transplanted in the same way as tubers, and will be vigorous in proportion to the amount of nutritious matter which has been accumulated in them. It is not yet certain to what extent the repeated cutting of the leaves for manufacture affects the development of the flower stalk, the increase of the root, and the formation of the new fans. And, indeed, the normal growth of this plant is a matter still surrounded with doubt. It is difficult to say what its full value may be, since maturity is not attained until after several years, so that the system of taking the leaves after two or three years' growth is no real test of its capabilities, and on this account the commissioners do not recommend its cultivation on an extensive scale, more especially as there is more than a sufficient supply of the raw material to meet a much larger demand than at present exists. Manufacturers prefer the *Phormium* that grows on high or dry ground, as it is purer, and more easily stripped than that found in swamps. There appear to be as many as 55 varieties of this plant, as distinguished by the natives, but it is believed that 20 marked varieties are all that can be accurately defined. The commissioners feel confident that *Phormium* has now acquired a permament hold on the market at a remunerative value, and that past failures have arisen, not so much from any fault inherent to the plant, as from want of experience. It is where there have been labor at a moderate rate, abundant raw material, and water for motive power and washing, that the fibre has been produced with the largest amount of profit. In every case, minute care and constant attention are requisite for the production of the finest descriptions and qualities of the fibre. The commissioners summarize the information they have collected by referring concisely to the chief points in the manufacture of a good quality of fibre. The selection of the leaves, which should have from 14 to 20 months' growth, and their careful preparation, is a matter of prime importance. Care must also be taken that the machinery be kept clean and in perfect adjustment. The washing of the fibre, after it has been reduced to finely-divided bundles, is essential, to secure excellence of quality, but long soaking is to be avoided, as tending to make the fibre soft and cottony. The rolling is advantageous when the washing has been completed, as it consolidates and defines the bundles, and the bleaching and drying which follow should be effected with rapidity. Scutching is the next step in the process, which, where the former parts have been efficiently carried out, should be performed rather with the view of burnishing the fibre than of reducing the quantity, by the production of a large proportion of tow. The use of oil is found to improve the appearance of the fibre, and also reduces its liability to undergo further maceration in water. It is best applied as the final stage of the scutching. The animal oil used by the natives is pronounced to be the best, and superior to the application of tar, which has an action on the fibre like that of acids. With respect to the baling, wire or hoop-iron is condemned. Scrim or other light cloth is in general favor for this purpose. The use of the plantain leaves for the Manilla bale suggests that the New Zealand fibre might be economically and safely baled in coverings made from its refuse leaves. The dimensions, also, of the Manilla bale are recommended. It measures 3 ft. 3 in. by 1 ft. 8 in., by 1 ft. 8 in., and weighs about $2\frac{1}{4}$ cwt. The commissioners urge that the name "phormium" should be adopted for this New Zealand fibre, as avoiding misconception, and being more in keeping with the names applied to the other roping fibres with which it has to compete in foreign markets.

The following tables are taken from the commissioners' report:—

From April, 1870, *to May*, 1871.

	Bales.
In five distinct qualities brought to public sale in London	36,008
Sea-damaged	87
Tow	1,546
	£. s.
Total value, reckoning 6 bales to 1 ton	140,506 0
Average price	23 8

	Relative Durability and Wear.					
	Circumference before experiment.	Circumference after experiment.	No. of days run.	No. of feet run at 4,575 per hour.	No. of miles run.	Durability per cent.
Dry:	in.					
Manilla	1.43	1.25	20	915,000	173 3	100
New Zealand (white)	1.56	1.25	28	1,281,000	242.6	134
" (tarred)	1.56	1.34	15	686,250	129.9	74
Wet:						
Manilla	1.43	1.12	22	1,006,500	190.6	110
New Zealand (white)	1 56	1.18	20	915,000	173.3	100
" (tarred)	1 56	1.34	19	869,250	164.6	95

It is hoped that a method of preparing the fibre before shipment, that will soften and divide it sufficiently fine to make it suitable for the manufacture of textile fabrics, will be ultimately crowned with success.

A FRENCH ARCHITECT ON THE ARCHITECTURE OF THE SECOND EMPIRE.

From "The Builder."

Frenchmen, naturally more emotional than ourselves, are more given to import their emotions into their business affairs. Since the downfall of the Napoleonic dynasty, and the crushing disasters which followed it, little has been publicly spoken or written in France on any subject whatever without an ultimate reference to the woes of the country and their supposed causes, or without an anathema hurled against the invader. The architects of France have, naturally enough, proved no exception to this rule. In graveside orations they have added a political lament to the expression of personal sorrow, and in written disquisitions they have endeavored to cast odium of failure on the shoulders of the *régime* under which they recently flourished. One of the latest architectural opponents of the Second Empire is M. Daniel Ramée, and his strictures have been admitted, under reserve, into one of the Parisian professional journals. The charges which he brings forward are numerous, and expressed in no measured terms. Many of his *confrères* differ from him; but many also agree with him, and in order that our readers may understand the views of those French architects who look on the darkest side, we translate a portion of his lengthy tirade. He says :—

During the eighteen years from 1852 to 1870, Paris and many other towns in France have completely changed their aspect. The venerable monuments which recall the national traditions and memories and glories of the past have been gravely marred and mutilated, cut down, and hacked about,—have even been thrown to the ground to make way for edifices of no intrinsic artistic merit. Moreover, a deplorable change has gradually taken place in the public taste, and particularly in architecture. There has, perhaps, never been an epoch which is richer in resources and materials of all kinds; and never in any epoch or among any people have public works absorbed a larger amount of the public money. Yet there has never been a people who, with so vast means of execution, have produced such paltry results, or results so sad and regrettable.

The degradation in which architects lay under the feet of the Second Empire arose from two principal causes:—first, the equivocal and pernicious management of new architectural schemes; and second, the thoroughly bad and insufficient education given to students destined for the architectural profession. It is of the first alone that we shall speak. Under the Second Empire everything was sacrificed to the consolidation of the throne of Napoleon, and in pandering to the depraved tastes of those who helped to establish it. Under that Empire architecture, like the other arts, was abandoned to intrigue, and partially to baseness, to masterly incapacity, to confusion, and to disorder. And architecture itself was without unity, without knowledge of its lofty purpose, without sincerity, without healthful fancy, and last of all without that elegance which is one of its chief attractions. All these faults arose from the absence of a capable, enlightened, independent, sagacious, and really national supervision. The ministry of Public Works was awarded by chance, by favoritism, or through the influence of those in Court favor, and was at the mercy of vain and inflated cliques, who utilized the power of office to carry out their own whimsical and fantastic caprices. Hence naturally emanated those servile and often burlesque conceptions in which oddity and frivolity predominate, in which a meagre and foolish fancy prevails, and which are marked by degeneracy of taste and a want of suitability to the times,—in short, which, while seeking to derive inspiration from the masters of the art, only succeed in bringing forth hybrid works without character; which are displayed, too, with impertinent assurance and stupid satisfaction before the public, in whom they excite little interest and still less admiration. For the real non-official public looked with a cold and indifferent eye on those edifices which cost it so dear, which it saw surcharged with blunders and inconceivable artistic liberties, and which are but bad imitations of the styles of the past on their decadence. This public was, moreover, disgusted with the boastfulness which thought to impose on enlightened and independent spectators; it was astounded at the audacious presumption which outraged and violated it, which provoked and annoyed reflective people, and which excited the contempt of all true artists.

The more we regard the architecture of the eighteen years of the Second Empire the more does it appear insipid and inconsistent. The works produced during that time are only an eternal reproduction of academic types, which have been stereotyped for years, and which it is fatiguing to encounter without variation on every occasion.

To pile stones on stones, mouldings on mouldings, columns on columns, to fill deformed niches with second-rate statues, or to raise them on pedestals and entablatures, to leave no blank space in the elevations, but to cover them over with debased profiles and sculptures of doubtful merit, to add ornaments which are of no conceivable use in the positions which they hold, except to mislead the eye, and detract it from the weakness and poverty of the architectural composition, has not resulted in the production of a real work of art, and has only given satisfaction to the vulgar and the interested creatures of the Empire, but never to those animated with a love of what is suitable and beautiful and true. The First, like the Second Empire, suppressed liberty, and used its every energy to hasten the national decadence, so that it might establish its own absolutism. The intellectual tone has been lowered, and all creations of the imagination have been less bright and glorious. The Arts were stranded in the universal shipwreck in which our military glory foundered. With very rare exceptions, the buildings of the Second Empire, tricked out in the unintelligent gaudiness of the *parvenu*, and hurried up with so much precipitation, reminds us of the structures of Augustus and of Constantine. To produce works quickly and abundantly, to prefer quantity to quality, seem to have been the device of these princes—and notably of the former—to consolidate their dynasties; and the Second Empire has not failed to pursue the same course with the same end in view.

RAILROADS IN PERU.

BY. F. J. CISNEROS.

Written for Van Nostrand's Magazine.

During the Presidency of Don Juan A. Pezet, in 1864, the Peruvian Congress passed a bill promoting the construction of easy and speedy railroads, for which, in addition to other subsidies, an annual interest of 7 per cent. during the period of 25 years, was also granted to any company that would untertake the construction of railroads at their own expense.

Many causes prevented the execution of these plans until 1868, when the President was authorized to make contracts for the construction of railroads "to Arequipa, Puno, and Cuzco; from Chimbote to Santa or Huaraz; from Trujillo to Pacasmayo and Cajamarca; from Lima to Jauja; and to all other places where they are needed."

Colonel José Balta, then President of the Republic, has until now endeavored to carry out the provisions of that bill, with the greatest energy, and he has succeeded beyond public expectation. So they have now in Peru 28 railroads, some of them in a working condition, some in process of construction, and the rest already nearly finished.

They are the following:

From Arequipa to Puno	232	miles.
" Arica to Tacna	39	"
" Callao to Oroya	130	"
" Chancay to Cerro de Pasco	120	"
" Chimbote to Huaras	172	"
" Eten to Ferrenafe	28	"
" Huacho to Sayan	36	"
" Ilo to Moquegua	63	"
" Iquique to Peña	45	"
" Iquique to Noria	37	"
" Lima to Callao	8½	"
" Lima to Chancay and Huacho	89	"
" Lima to Chorrillos	7	"
" Lima to Magdalena	3	"
" Lima to Pisco	145	"
" Malabrigo to Ascope	28	"
" Mollendo to Arequipa	107	"
" Cerro de Pasco to Pasco	15	"
" Pacasmayo to Guadalupe	14	"
" Pacasmayo to Magdalena	69	"
" Paita to Piura	63	"
From Pisco to Ica	48	miles.
" Pisagua to Sal de Obispo	35	"
" Juliaca al Cuzco	209½	"
" Salaverry to Trujillo	10	"
" Tacna to the Bolivian frontier	108	"
" Tacna to Puno	301	"
" Trujillo to Eteu	148	"

The whole length of these roads is 2,310 English miles, or 3,716.80 kilometres, of which about 500 kilometres were in operation at the end of last year, viz.: from Eten to Chiclayo, from Lima to Chancay, from Lima to Callao, from Lima to Chorrillos, from Pisco to Ica, from Mollendo to Arequipa, from Tacna to Arica, from Iquique to Norria, from Lima to Cocachacra, and from Cerro de Pasco to Sacrafamilia.

Many local exigencies have prevented the completion of all these lines, but every body in Peru understands the advantages of having a net of rails throughout the territory. Peru possesses extensive forests with valuable timber, rich mines and fertile lands, separated from the coast by high mountains, making the transportation of their productions so expensive that nobody considers them as an element of productive trade. Of course, railroads will develop all these riches, and will pour them into the foreign market.

The railroad from Tacna to the frontier of Bolivia, will be very useful to this State, a country so abounding in mineral and vegetable wealth. Some foreign speculators have undertaken the construction of this road and the Peruvian Government will give about $6,000,000, the third part of the capital needed.

Bolivia will also profit, through Lake Titicaca, by the construction of a railroad from Arequipa to Puno.

All these projects, when carried to execution, will considerably increase the prosperity of Peru, and will finally communicate by connecting the interior lines, the shores of the Atlantic with those of the Pacific Ocean. Until now nothing has been made to connect the interior lines, but the communication with the Atlantic would be an easy undertaking by prolonging the Lima and Oroya railroad to Acobamba, Fuerte, San Roman, and Maïro, hence to the confluence of the River Pachitea and Ucayali. From this river to the Amazon, navigation is very easy.

Another way of reaching the Atlantic would be by the prolongation of the Juliaca and Cuzco railroad. Urubamba river, which passes near Cuzco, is not easily navigated from Mision to Mainiqui, but from here to its mouths many travellers assure us that navigation is entirely safe. Between Cuzco and Mainiqui there are 210 miles ; both places being united, the southern part of Peru will have an easy communication with the Atlantic. We are almost sure that both projects will be carried out, although great expense must be incurred on account of the obstacles of the surface because that part of the country possesses many valuable riches, and Bolivia needs that communication for her foreign trade.

Besides, the enterprise of constructing a railroad from Lima to Oroya, and from Puno to Cuzco, is in the hands of Mr. Henry Meiggs, and he, knowing the advantages of such communications, will undoubtedly conquer, with his indefatigable energy, every obstacle that would deter many another enterprising capitalist.

The name of Henry Meiggs is connected with the most important enterprises in Peru. Besides the construction of the above-mentioned roads, the Government has authorized him to construct the railroads from Mollendo to Arequipa, from Arequipa to Puno, from Ilo to Moquegua, from Pacasmayo to Magdalena, from Pacasmayo to Cajamarca, from Pacasmayo to Guadalupe, and from Chimbote to Huaraz.

Mr. Meiggs has not confined himself to railroad enterprises. He is now superintending the building of 1,000 houses on the ground where the walls of Lima were once erected. He has asked also permission to establish a line of cars around that city.

Peru has sufficient resources to carry out the most expensive projects, as can be seen by the following statistics of her imports and exports :

	Import.	Export.
From Callao yearly	$24,000,000	$48,000,000
" Iquique "	4,800,000	7,200,000
" Arica "	6,500,000	3,156,245

The principal article of exportation is the *guano*, of which are exported through Callao 500,000 tons, valued at $20,000,000.

According to the statistics published in Lima, in 1868, 7,175,195 tons of *guano* were exported from the 19th of February, 1842, to the 31st of December, 1867. Total value, $218,693,625.

Besides *guano*, a large quantity of nitrate of soda is yearly exported through Iquique. The exportation of this substance increases daily, and in 1870 amounted to 147,205 tons, the value of which was $8,832,000.

The incomes and expenditures are as follows :

INCOME.

Guano 1,181,327 tons,	$44,915,451
Duties on export	4,818,000
" on import	229,600
" on tons	246,000
Tax on real estate	195,300
Duties on patents	185,900
" on stamps	374,100
" on mails	123,100
Other incomes	7,895,400
Total	$58,982,751

EXPENDITURE.

Interior police	$6,460,004
Foreign affairs	490,043
Justice, public instruction	4,632,333
Army and navy	10,870,762
Finances, commerce	4,812,564
Payment of public debt on public works	30,729,058
Total	$57,913,764

Leaving a surplus of $1,069,087.

Although many new expenses have been incurred since the publication of these figures, Peru still has sufficient means to carry into effect all her important enterprises ; her resources are inexhaustible ; new ones are daily discovered.

The railroads are developing the riches of the interior provinces. In the department of Ancachs, where they are now constructing a railroad from Chimbote to Huaraz, the land produces every kind of fruit ; gold, silver, and copper mines are found there, and it is assured that coal is also found there in large quantity ; this article, imported from England, at present being very dear on the Pacific coast. Thus the working of the mines in that department will greatly increase the revenue of Peru. This country needs only peace and easy communications to furnish the world with many precious and valuable articles.

May everlasting peace give to her enlightened population the means of developing industry and commerce, and that part of our American continent will be, in the course of a few years, a centre of activity and an emporium of nature's choicest riches.

New York, *February*, 1872.

COTTAGE BUILDING IN NORWAY AND SOME OF ITS TEACHINGS.

From "The Builder."

In the present state of things architectural, so confused, and with so much that indicates a fast-coming change, it must be not a little interesting to inquire into the work and methods of work of those who have *not* had, as we have, vast heaps of arts "precedent" to go by and to copy. It is not a little singular to reflect on that it has been reserved for these modern days to be so entirely at the mercy of what has gone before. In no other age of the world has the architect of the *then present* been at the mercy of that which preceded it. It never would seem to have copied,—always followed or seconded. Each age or generation took up the work as left by those who preceded it, improved on it or not, as the case might be, and so, in effect, left behind them practically a new style, a growth out of that which preceded it. It did not copy or make effort to reproduce what had gone before, but simply went on with the work, and, by degrees, worked out a new style. Nothing can show this more convincingly than the primitive system of hut or cottage building in Norway,—*i.e.*, in those parts of it removed from the influences of modern and new systems of construction and new and patent materials. The subject is a curious one, and worth a little consideration and inquiring into, if only as a primitive system of doing things before style commenced, and before any one ever thought of copying. How to build architecturally and artistically, without any architectural precedent—in other words, to build up mere material constructively and ornamentally,—is an important question. It has been contended that this cannot be done,—that some definite architectural forms and ornament are absolutely necessary; and that these are the work of time and growth, and that no "architecture," in its full meaning, can come out of mere and simple construction; but it is a little wonderful to see, if you look a little below the surface, how much of architecture is to be found in the simply and rudely constructive. Before we go further, it is not a little to be regretted that no trustworthy system has as yet been invented of rendering wood *fire-proof;* for the want of it, and the consequent disuse of timber construction, have thrown wood-work into the background. No wooden houses, where any sort of building art prevails, are now possible, so that timber-house construction and fine art are of the past. This is to be regretted. A complete history of wooden house-building and architecture with wood only for its material, is to be gathered in Norway alone; indeed, this history may be said to go back beyond the historic era, for there are evidences of wooden buildings on piles, of a date far beyond written records. Architecture grew up here and there, doubtless, out of materials and simple and necessary construction, each separated nationality or race having its own.

But the main practical interest of the subject lies of course in the strictly modern plan of hut or cottage building, as it exists, and as people now live in such buildings. Of course we are speaking only of the purely *native* system of building proper to the country, and not of that which is gradually superseding it, and which has been borrowed from foreign sources. These cottages are formed of pine logs, but roughly squared, with the sharp edges cut off so as to be nearly octagonal. These logs are laid one upon another, and with a layer of moss between them in lieu of mortar. The logs forming the side or end walls are notched, so as to receive the ends of the timbers forming the front and back walls. Each log is from 12 in. to 13 in. or more square, so that the walls are about a foot thick. The walls are about 10 ft. high. In the better sort of cottages the whole of the interior of the rooms are lined or panelled, so that it would be difficult to discover a better system of building, or one more entirely suited to the climate. A warmer kind of walling could not be devised, nor one more "comfortable" in appearance. The floors and ceilings are boarded, the former, raised from the ground by stone sleepers, a foot or two high. We hardly know what will be said about the *roof;* but why should a clever thing be lost sight of? Improvement of course is introducing *slate*, always neat, if not genteel; but the poor old Scandinavians look to warmth and comfort, and perhaps to harmony and picturesqueness, if not to the "architecturesque;" and they covered their rough roofs with close boarding, then with birch bark peeled off in flakes; and then on this they laid earth about 3 in. in depth, retained by a fillet running along the eaves. A crop of moss of course soon covered this earth, so that a more picturesque or better colored roof could not be, or a warmer or better heat-protector or keeper-out of cold. The joiner's work is but rough, like the walls and roof, but all harmonizes, and may truly boast of one good quality—it keeps out the wind and the weather! Surely such a system of building as this is as good as can be for the place it is in, and for the surroundings of rude forest and rapid watercourses and lakes. Some might think this a better way of building a cottage than the thin-walled and meagre model cottage, which is, says a good authority, but "the skin of a house." The old Scandinavian and his not yet thoroughly civilized modern successor think nothing does but the solid timber logs between them and the cold. Nothing, indeed, can be more *comfortable* than the interior of one of these wood-walled and wood-lined rooms. With the prosperous Scandinavian there is always a room for everything, for the material being so plentifully supplied by a bountiful nature, there remains but the trouble of building and putting together. Many of the houses are two-storied, and the stairs, from the ground to the upper story, are sometimes singuarly quaint and architectural. Now, this is an old-fashioned way of work, and rough as may be; but we may ask, what workman is there that would not sooner live in such a tenement than a in patented, thin-walled, and corrugated iron roofed model-house of the most recent make and pattern, and choke-full of scientific inventions and improvements?

It will thus be seen—at least, to some small extent—that in this far northern and somewhat out-of-the-way country there now exist materials for forming some idea as to the origin if not creation of a style of architecture, the growth out of mere *constructional necessity*, and out of the materials afforded so abundantly by nature on the spot whereon it has grown up. We cannot in looking at it avoid the pressing thought of how much light is thrown analogically upon the origin and progress of Gothic architecture in these islands, for both are the results of Northern thinking out and requirements. We say "Northern," and use the word in place of a better, and as descriptive of the doings artistically and architecturally of a people distinct from Southern and Eastern races. It leads us, too, to the much-vexed question, now especially interesting, of how far is it possible to *invent* an entirely new style of architecture? Is it possible to create a new style of architecture to be founded on, and to grow out of, simple and necessary construction? and can it be accomplished in *one* age, or even so far carried on in one as to show itself as a something distinct in that age, and will the study of all other styles help or hinder it? No small amount of discussion might be raised on such a revolutionary project, and without something to go by,—"precedent" of some sort or other. There are some who might even go so far as to say the thing is impossible in the very nature of it. One thing, however, this Northern work undoubtedly shows, and it is this, that art and architecture may grow out of bare construction with "precedent," or a something to go by, entirely absent. This simple architecture harmonizes perfectly with the scenery and surroundings of the place it fills. There is no jarring element in it. As to the modern transplanted villas and smart houses, you wonder where the latter came from, and who could possibly have imported them, so fearfully do they put out nature,—the nature which surrounds them,—a primeval forest growth, nature's own work, and which, as it would seem, man cannot without more capital and science destroy. What a pity it is that "improvement" has not stayed its hand here and there, and left us a town or even a small village from the old days,—some small collection or group of houses, whereon no disturbing artistic element would be found, with its quaint inn, irregular streets of houses, so truly "picturesque,"— its small church, and all those other little quaint things, once upon a time to be seen everywhere. A litle of this, as all know, is to be found here and there, and the antiquary and the architect have ransacked England to find them out, and to transmit them to posterity on paper; but the things themselves are fast disappearing, and must soon be numbered with the things that were. But in Norway these strange things are yet to be seen, and a curious light indeed they throw on things architectural and artistic.

VERTICAL ENGINES FOR THE NAVY.

From "The Engineer."

The engines in our iron-clad ships break down so frequently that their incessant failure begins to cause much uneasiness among engineers. It is no new thing for a marine engine to break down, but until within the last few years the thing broken was almost invariably the crank shaft. This species of casualty has, however, become more and more rare, as better materials and improved methods of manufacturing them have been adopted. We scarcely ever hear in the present day of the breakage of a screw shaft in our navy, and the reason is obvious. Not only are these shafts very well made, but they escape the deteriorating influences continually operating in the mercantile marine. In other words, they do so little continuous work that the metal of which they are made is not fatigued. The distance run under full steam in any one year by any one of our iron-clads is excessively small; it is as nothing, indeed, when compared with the service got out of the engines of any large full-powered screw steamer carrying mails, passengers, and cargo. The principal casualties to which our naval engines are liable are almost unknown in the mercantile marine. They consist in the splitting of cylinders and condensers, and they recur with the most alarming pertinacity. We have seen why it is that the crank and screw shafts of our iron-clads last very well. It remains to be seen why the rest of their machinery is not equally permanent; and we have reason to believe that this question is now receiving the most anxious consideration from at least one eminent firm of marine engineers. We have already expressed our opinions on this point; but the enormous importance of the subject, which affects the efficiency of our navy quite as much as any question connected with guns or armor-plating can do, is a sufficient excuse for returning to it again. We start from this point with two propositions. The first is, that the principal cause of the splitting of cylinders—to say nothing of certain other casualties of far less importance—lies in the horizontal position of the engines. The second proposition is, that in iron-clads it is unnecessary to to adopt the horizontal type. We have so fully and recently discussed the first of these two propositions* that we shall only allude incidentally to it now, and devote our attention principally to the second point—namely, the feasibility of using vertical engines in our navy.

Very early in the history of steam navigation it became evident that in war ships it was essential that engines and boilers should be kept well below the water line. The Amphion, engined by Messrs. Ravenhill, Salkeld & Co., was the first ship the machinery of which complied with this condition. Up to the time of the Russian war paddle-wheel war steamers were actively employed, but ever since no choice has been left with the marine engineer. He has been compelled to keep his machinery below the water line, and a very great stimulus has, therefore, been given to designers of horizontal engines. As the art of defending ships with armor plates progressed, however, greater scope was afforded to the marine engineer for carry-

* Vide The Engineer for January 19th and February 2d, 1872.

ing out his views, and the necessity for keeping all machinery well down in the ship grew less and less. A prejudice in favor of the horizontal engine for war ships was, however, unfortunately established, and to this day, although the necessity for seeking protection below the water line has long since passed away, engineers still adhere to the original practice and put engines for the navy on their sides. If we glance at the history of the screw engine in our mercantile marine, we find that at one period horizontal engines came into fashion. They were in favor for her Majesty's ships; and as the the best possible engines, it was assumed, found their way into the navy, private shipowners could not do better than adopt the same type. The desire to have horizontal engines in merchant ships did not last long, however, and for several years nearly all the marine engines used in our merchant service have been of the vertical type. There are a few exceptions to this rule, of course, but they are too rare to affect the question materially, if at all. Now, it is certain that our great steam shipping companies know perfectly well what sort of machinery answers their purpose best, and as they are wealthy, considerations of cost stand little, if at all, in their way. If, then, the vertical type is used, almost to the exclusion of the horizontal type, in very large steamers intended to be always ready when wanted, and to be as free as possible from the chance of break-down, why should the gentlemen who supply engines to our navy adhere blindly to the horizontal type virtually rejected long since by the shipowning community? The necessity for using the horizontal or low type of engine passed away as soon as armor plating assumed importance; and it is almost, if not quite, certain that machinery is safer in the present day behind 6 inches of plating than it can possibly be below 6 ft. of water. If it is deemed necessary to plate our ships far below the water-line, then it follows that the water cannot give sufficient protection until we arrive at a point considerably below the lower edge of the armor plating; but no one dreams of applying this rule to the marine engines of our navy. Indeed, it would be impossible to keep them down far enough in any ship. Therefore we already depend upon armor plating for their protection. Why not carry the principle a little further, and, relying wholly on the plating for protection, adopt that form of engine which is most suitable for the intended purpose?

It may be argued that the space taken up by vertical engines would be too great, but this is contrary to fact. Such engines really occupy less useful space than any horizontal engine; the place occupied by the upper portions of the machinery usually being left totally unoccupied. In ships of war as well as merchant vessels, it is essential that there should be a good roomy hatchway—in other words, that there should be a portion of the deck next above the engine-room floor cut away—for the purpose of securing ventilation and light to the engine-room. In this space could stand the cylinders or guides of a vertical engine; while in our war ships of great beam much valuable space now taken up by the engines would be rendered available for stores, or even coals. It must also be borne in mind that the stroke is in modern screw engines always short, 4 ft. 6 in. being the maximum. Great power is had by running pistons of enormous diameter at a very high velocity, but the height of an engine is measured by the length of stroke, and therefore it will not do to urge that, although vertical engines of 450-horse power nominal may be got into a reasonable space measured vertically, yet that it would be impossible to do the same with engines of double the power. As a matter of fact very small engines may take up just as much height in a ship as engines of the largest size. So long as the length of stroke is kept within moderate limits there is no danger that the engine will be too high.

As to the kind of vertical engine to be adopted, that must be settled by the conditions which will obtain in each particular case. The return piston-rod engine, set up on end, will be the best under some conditions, the inverted trunk engine under others. We are not prepared to advocate the adoption of very large engines of the steam-hammer class, as the great weight of the cylinders may act prejudicially in such cranky craft as some of the recent additions to the navy. But no marine engineer of experience will meet with the least difficulty in designing perfectly safe and trustworthy vertical engines capable of indicating 6,000 or

7,000-horse power, provided he has all the space allowed him which a great iron-clad can legitimately place at his disposal. We may add that in our opinion it will be found far better in the long run to get these excessive and abnormal powers out of three or even four cylinders of moderate dimensions than out of two only of colossal diameter. There should be no difficulty in expanding steam five times in a four-cylinder engine, each cylinder giving out, say, 1,000 to 1,200-horse power, and the expansion beginning and ending within it. The balance would be perfect, and the strain on the crank-shaft extremely uniform. It is probable, too, that the cost of such an engine would be slightly less than that of an engine with only two huge cylinders, difficult to cast and to handle; and while the chance of a break-down would be reduced with the diameter of the cylinders, so it is clear that even if one engine did break down, the ship would still remain efficient so long as the the other three engines were uninjured, which would not be the case with any of the ordinary double-cylinder marine engines. If it were determined that engines of the compound type must be adopted, then, probably, the best results would be had from an engine consisting of three vertical cylinders, disposed side by side, the two small cylinders standing fore and aft of the large cylinder, and exhausting into a receiver from which it would draw its supplies. Each of the three cylinders would, of course, work a separate crank, set at such an angle with its fellows as to secure the maximum regularity of motion.

THE LIME PROCESS CONSIDERED WITH REFERENCE TO THE PRESENT STATE OF THE SEWAGE QUESTION.

From "The Building News."

The employment of lime for the clarification of sewage water was, in all probability, suggested by what is known as "Clark's process for softening water." Carbonate of lime (the usual source of hardness) is soluble in pure water to the extent only of about two grains per gallon, though it is found freely dissolved in what are termed "calcareous waters," owing to the presence in them of carbonic acid, which acts as a solvent. When this gas is expelled (as, for instance, when the water is boiled), the carbonate of lime held in solution through its agency is deposited, resulting, in the case of steam boilers, in the formation of the so-called "scale." The plan of softening water devised by Dr. T. Clark consists in the addition to it of a slight excess of milk of lime, which, by combining with the free carbonic acid, occasions a precipitate of carbonate of lime. This precipitate carries down with it the carbonate of lime previously held in solution by the acid, in the form of fine crystals, together with any coloring or organic matter which may happen to be present. The water is thus rendered, in the course of a few hours and at a very trifling expense, perfectly bright and clear.

Sewage water, which may be regarded as water containing fram 50 to 150 grains per imperial gallon of mineral and orginic impurities, lends itself admirably to such a system of purification as that which has just been described. On the addition to sewage of from 2 to 42 grains per gallon, according to its strength (by which we imply the amount of the impurities in it), of slaked lime, a bulky precipitate is formed, which entangles the floating particles of organic and solid matter, and as it gradually settles, leaves the supernatant water perfectly clear, and, to a considerable extent, deodorized. The above treatment constitutes what is known as the lime process, and this plan of dealing with sewage, in spite of Dr. Clark, has been several times patented, and partly perhaps on account of its simplicity, and partly because of its cheapness, seems to have been always a favorite one with sewage experimenters. It has more than once been carefully investigated by Royal Commissioners, and the relative advantages and disadvantages arising from its use have formed the subject of considerable differences of opinion.

It may be as well, before going any further, to glance briefly at those printed reports upon this process which are available, among the more important of which we may name that of Messrs. Hofmann and Witt, forming Appendix 1 to the Report on the Metropolitan Drainage, 1857; Professor Way's Report on the Deodorisation of Sewage, being Appendix No. 6 to the Second Report of the Sewage of Towns Commissioners, 1861; and the remarks upon the treatment of sewage with lime, vol. 1, p. 52 *et seq.* of the First Report of the Rivers Pollution Commission, 1870. In connection with these, we may examine also the Report of Dr. Letheby, forming Appendix No. 4 to the Report by Messrs. Bidder, Hawksley, and Bazalgette on the Main Drainage, 1858.

When, in 1856, certain referees were appointed to investigate the main drainage of the metropolis, it was deemed essential at the outset of the inquiry to ascertain the value of sewage, and the practicability of utilizing it. Dr. Hofmann and Mr. Witt were accordingly requested to furnish a report upon the subject, which they did under date of July 1st, 1857, and the information thus obtained may be said to have laid the foundation for all subsequent estimates, not only of the value, but also of the possibility of successfully utilizing sewage. Among other processes for the treatment of sewage, these gentlemen paid considerable attention to the plans adopted at Leicester and Tottenham involving the use of lime, and for several reasons, which we may now proceed to examine, they rejected it as unsuitable for the metropolis.

It is almost unnecessary that we should here pause to explain that we possess in sewage a very valuable manure, and that all the precipitation processes aim not only at the removal from the sewage water of its impurities, but also at the production from the solid residue of a sal able manure. Now when Messrs. Hofmann and Witt came to examine the dried residue from the lime process, they found that in lieu of being a valuable manure the deposit contained only one-twelth part of the fertilizing materials present in one ton of guano, and hence they argued that the farmer would have to cart on to his land and spread 12 tons of the lime manure to produce an effect equivalent to that obtained by employing one ton of guano. It was very easy from this to prove that beyond an area of two miles from the works the extra expense of cartage and spreading would do away with all profit on this manure. When, further, it was shown, firstly, that in the effluent water, after the liming, there remained two-thirds of the valuable ingredients of the sewage; secondly, that neither the lime nor any other precipitant removed the whole of the soluble organic matters, which were especially liable in hot weather to undergo putrefaction; and, lastly, that the estimates of the probable cost of the process were based upon insufficient data, it may readily be imagined that their opinion was unfavorable. They, however, admit, in an extract from their report printed as a foot-note to page 22 of the report of the referee—which is not, strange to say, to be found in their report as given in the appendix—that "If we were asked to select one of the processes as particularly calculated to furnish satisfactory results, we should certainly give the preference to the lime process." In the course of their observations, they state that the quantity of the soluble organic matters found in the river after admixture with the sewage, is very minute, and they give no reasons for their subsequent statement, and the one upon which they ground their principal objection to this process—namely, "that the fluid run off from the sewage deposit might very seriously affect the river."

From a careful consideration of their experiments, we have little hesitation in affirming that they did not give the lime process a fair trial, though their results, as far as they go, are otherwise very satisfactory and conclusive.

The sewage water selected by them for the purpose of precipitation by means of lime and taken from the Northumberland sewer, was very concentrated; that is, in one gallon, or 70,000 grains, it contained no less than 160.09 grains of suspended and dissolved matters. To each gallon of sewage water 20 grains of "common gray Dorking lime" were added, after being carefully slaked. Now, Dorking lime is burnt from the lower chalk, and rarely contains less than 10 per cent. of silica, iron, and alumina, and frequently much more. If we assume that the lime used by Messrs. Hofmann and Witt had this percentage of clay, we find that they would thus get only 18 grains of pure lime capable of taking hold of the acids in the sewage. For this purpose the quantity named would be wholy insufficient, and the precipitation would therefore be incomplete. That such was the case there can be but little doubt, for we are told immediately afterwards that after the lapse of three hours "the supernatant fluid was still opalescent," and that "the whole of the suspended matter had not been completely removed by the process." This description quite tallies with what takes place when the lime used is not, if anything, slightly in excess; a fine granular precipitate is then thrown down, which does not clear the water, and settles only after many hours. But we have other data to go upon in forming our judgment —namely, the amount of the precipitate they obtained.

	Solid constituents originally present.	Composition of supernatant fluid.	Amount separated.
Organic matter........	88.76	40.34	48.42
Mineral matter........	71.73	55.68	15.65
Total......	160.09	96.02	64.07

N. B.—These 64.07 grains doubtless contain the greater part of the 20 grains of lime.

From 160.09 grains of matter in solution and suspension, a precipitate is obtained of only 64.07 grains on the addition of the 20 grains of lime. Further, it seems to us very remarkable that although 20 grains of mineral matters have been added to the sewage, we have only 15.65 grains in the precipitate, and no increase has taken place in the total impurity; for on adding together the grains per gallon present in the supernatant fluid and in the precipitate, 96.02+64.07, we still get 160.09 grains. Here a very probable error, and one which makes a vast difference to all the subsequent calculations founded upon this table, occurs to us. The analysis is headed "Effect of Treatment with Lime (deduced from comparison of analyses of the original sewage with the analysis of the supernatant fluid after separation of the deposit)." From this title it is manifest that, as their results are mere deductions from two independent analyses, the figures 64.07 grains, which are evidently obtained by subtracting the 96.02 grains found in the effluent water from the 160.09 grains ascertained to have been present in the sewage before treatment, do not make any provision for the 20 grains of Dorking lime which were used for the purpose of precipitation. The 96.02 grains in the effluent water should really have been deducted from 160.09+20 grains, giving a residue of 84.07 grains in lieu of 64.07. This latter value is much more like the truth, for if we contrast the analyses of Messrs. Hofmann and Witt with those of other observers, we find that in every case the amount of the precipitate, even when a proportionally much smaller quantity of lime is used, is always over 50 per cent. of the total impurities in the sewage.

In the table on next page we have taken the results given in the reports of the various Royal Commissions, and the engineers consulted by the Metropolitan Board of Works, and so arranged the various calculations as to compare with the amounts obtained by Messrs. Hofmann and Witt. The only case in which lime has been used in considerable excess —namely, to the extent of 42 grains per gallon, is that given upon the authority of Mr. William Higgs, in the Appendix No. 4 B. to the report of the engineers before alluded to. The effect of this quantity of lime upon sewage taken from the same place, and but slightly richer than that experimented upon by the former observers, was the separation from it of a precipitate amounting to no less than 164.4 grains per gallon, leaving litle more than two-sevenths of the solid impurities in the supernatant water in lieu of the residue of three-fifths shown in the case of the previous experiment.

By good fortune we possess a third series of investigations upon the same sewage conducted for the Sewage of Towns Commissioners by Professor Way, which will be found at page 69 of their second report. The sample of sewage water operated upon by him, and taken only a year later, is much weaker than the former ones, containing as it does only 127.3 grains per gallon; but the amount of lime employed, between 15 and 16 grains to the gallon, was also proportionately less. With four grains less lime and much weaker sewage, the precipitate obtained by Professor Way is five grains in excess of that given by Messrs. Hofmann and Witt; and as the results in this case are not mere deductions, but are founded upon careful analyses taken at each stage of the process, they may be considered, we believe, entirely reliable.

Name of Town or Sewer.	Date when Collected.	Solid constituents originally present.		Total in grains per gallon.	Lime used in grains per gallon.	Precipitate obtained.		Total in grains per gallon.	Percentage ratio of the quantity originally present.	Solid constituents of supernatant fluid.
		Organic.	Mineral.			Organic.	Mineral.			
Northumberland wharf .. .	May 16, 1857	88.76	71.33	160 09	20	48.42	15.65	64.07	40.02	96 02
Northumberland wharf	February 3, 1858 .	65.00	108.00	173.00	42	49.80	114.60	164.40	95.02	50 60
Northumberland sewer	March 2, 1859 ...	58.50	68 80	127.30	15 to 16	35.41	34 09	69.50	54.59	71.98
Average of city sewers (day)	May to July, 1857	32.14	61.75	93.89	12	21.06	33.39	54.45	57 99	51 44
" " " (night)	" " "	15.25	63.82	79 07	12	9.90	18.54	28.44	35.96	62.63
Leicester	" " 1856	20.79	85.68	106.47	12?	14.83*	39.31*	54.14*	50.85	64 33
Leicester..................	July 30, 1868	..	..	117.99	12?	40.18*	24.01*	64.19*	54.49	65.80
Average............	....	..	..	116.29	..	..	..	72 52	62.36	..

* Estimated from effluent water, and analysis of dried mud.

It is not necessary to adduce any other instances, as we think we have said enough to show that the arguments founded upon the above results lose much of their weight when the premises are found to be so fallacious. Many of the calculations of quantity, price of production, etc., are entirely altered by substituting 84 grains for 64.

We have already said that no reasons are given by Messrs. Hofmann and Witt for the opinion they express that the effluent water from the lime process, when diluted with over 200 times its volume of river water, is likely to become a nuisance, and on turning to Dr. Letheby's report, we find that he entirely disagrees with them. Indeed he goes so far as to say, "I am quite sure that the process of defecating the sewage of London by means of lime can be effected with advantage and perfect safety, and the discharge of the clear sewage water into the Thames will not be a source of danger or discomfort to the public."

The report of the eminent engineers who associated with themselves Dr. Letheby is as decisive in favor of the lime process as the referee's report was adverse to this mode of treatment. When speaking of the outfall tanks they say: "The reservoirs are proposed to be constructed so as to enable the precipitation of the sewage matter to be effected by the application of lime. . . . "We can speak positively to the fact that the process is most successful; the water is completely deodorized, as well as rendered bright and tasteless. It does not subsequently become putrescent, though diluted with only twice its bulk of other water." The reason they bring forward against its adoption is the worthlessness of the resultant mud, because, "when produced in large quantities, the precipitated matter is unsalable, and must be removed at considerable expense."

In their second report, the Sewage of Towns Commissioners condemn the process upon similar grounds, though they also allude to the danger there is of the decomposition of the effluent water from this process, when the therein-contained organic substances "are placed under the necessary conditions of temperature, air, moisture, etc." They conclude by stating that "the lime process, though very simple and the least costly of any, is far from perfect," which, as far as concerns the last part of the sentence, may, we fear, be said with equal truth of every plan of precipitation yet proposed. We must defer to another occasion the examination of the remaining reports, and the consideration of the value of the lime-sludge as a manure.

THE SEINE.*

From "Nature."

In carrying out the great works for the improvement and embellishment of Paris under the late Empire, all incidental discoveries of objects relating to art, history, and science, were systematically investigated, recorded, and preserved, instead of being left to the chance and uncertain description of casual and independent observers. In a liberal and enlightened spirit the Municipality of Paris and the Préfet of the Seine, M. Haussman, established a proper organization and a staff (*Service des fouilles et des substructions*) to follow up such discoveries, to take plans of old works, to preserve all art treasures or objects of scientific value ; to note, in fact, and to investigate everything of interest. Men eminent in several departments were consulted, and engage to draw up reports with full illustrations of the discoveries. By these judicious measures, the knowledge of the topograpy, antiquities, and archæology of Old Paris has been greatly advanced. Works of the Roman, Gallic, and Mediæval periods have been brought to light, surveys and plans made, and the more important specimens preserved *in situ* or in the public museums.

To M. Belgrand, the eminent and able engineer for the water supply and drainage of Paris, was deputed the work of recording all the geological and some of the archæological facts discovered during the construction of the large works on which he was engaged.

Paris up to the last few years had been supplied with water from local sources (river, canal and wells), but as these were found insufficient and of indifferent quality, it was determined to seek for other and better sources of supply at a distance, and some large springs in the chalk district, respectively distant 60 and 84 miles from Paris, were eventually selected by M. Belgrand, and their waters were brought to Paris by means of aqueducts on a high level. In carrying out this great work, M. Belgrand made himself intimately acquainted with the hydrography of the Basin of the Seine. He explored every valley, and determined the *régime* of every important river. The result of the first part of the inquiry appeared in a valuable series of tables, showing the connection between the rainfall and the discharge of each river—the extent and nature of the floods, and the geological character of the ground with reference to the range and extent of the permeable and impermeable strata, and which he illustrated by a specially colored map. In connection with the construction of the aqueducts, M. Belgrand had also to ascertain the nature of the surface and the contours of the hills and great plains along which he carried them, and to examine the many pits whence the materials for construction were obtained. This geological investigation led to the discovery of many interesting specimens, and further suggested many theoretical inquiries relating to the origin of the present surface, and to the *regime* of the old Seine during the later geological periods. The result of the inquiry is embodied in the three handsome quarto volumes before us—one of 255 pages of text, with 106 pages of introduction, descriptive of the country, and giving the theoretical views; a second containing plates of fossils, of flint implements, and pit sections; and a third with extended colored sections and a monograph by M. Bourguingnat of the shells found in the Drift beds.

Paris stands on Tertiary strata, from beneath which, at a distance of some miles, the chalk crops out and forms a belt many miles in width. These formations constitute a table land having a height of 100 to 200 ft. along the sea coast of Normandy, and rising from 500 to 600 ft. inland in Champagne. This district is traversed by the Seine and its tributaries, flowing in comparatively narrow valleys cut deep into the table land; while on the extended upland plains thus formed, there rise, here and there, ranges of hills of Fontainbleau Sands or other later Tertiary strata. The strike of these hills is in a direction entirely distinct from that of the hill slopes flanking the river valleys and forming part of the present river system. The latter range in various direc-

* From a review of "Le Bassin Parisien" aux Ages Antehistoriques," par M. Belgrand.

tions—north, north-east, south, and south-east—in accordance with the direction of the tributaries of the Seine, until they join that river, the main channel of which has, from Montereau to the sea, a general direction south-east to north-west. M. Belgrand found that the hills on the plains nearly all ranged in this one given direction, or approximately from south-east to north-west, with intervening valleys having the same direction. Numerous such ridges, none being of any great length and all narrow and having this definite trend, are found to extend over the whole plateau area uninfluenced by the more tortuous deeper river valleys which intersect the same area at various angles to their course. The river-valleys are covered with gravel formed of the *débris* of the rocks through which the present rivers flow, while the plateau valleys and plains are free from such *debris*, but are covered with a uniform layer of red clay or loam. Whence M. Belgrand concludes that the two systems of valleys have a different origin. He contends that it is not possible to have a true river channel without having more or less drifted gravels formed by the constant action of running water and by floods, and therefore that these higher valleys could not have been formed by river action, while at the same time their rectilinear and special bearing indicates that their formation is due to one common and independent cause.

M. Belgrand considers that the only explanation which will account for the phenomena presented by these higher-level valleys and hills, is the rapid and transient passage of a large body of water over the surface; and as the excavation of these higher valleys took place after the formation of the Fontainbleau Sands and of the Calcaire de Beauce (Miocene), and before the Pliocene period (for the *Elephas meridionalis* of the valley of the Eure shows that the land had then emerged), and as also, according to M. Elie de Beaumont, the elevation of the main chain of the Alps took place at the same period, M. Belgrand connects the two events and supposes that the sea of the Pliocene deposits of the Alpine area was thereby displaced and that it swept over this northern portion of France, denuding the softer portions of the strata and leaving narrow ridges of the harder portions all trending south-east to north-west (or in the direction from the Alps), standing out, on the denuded high plains, as monuments of its passage. M. Belgrand points out that where the Tertiary strata have presented a resistance which the waters could not overcome, the high-level valleys formed by the diluvial waters are, in such cases, fronted in the opposite range of hills, against which the mass of waters impinged, by a deep bay cut by the current in those hills, and that the waters thus checked in their course were turned off at acute angles, until they reached the main channel of the Seine, tending thereby to form secondary or tributary valleys, which, when the deluge had passed, contributed, with the Seine valley, to form the present lines of river drainage. Such volumes of water as we have depicted would, he argues, have swept the higher channels and plains clear of *debris*, leaving the denuded area covered merely with the silt thrown down from muddy waters, and depositing the coarser *debris* in the middle and lower range of the deeper channels through which the present rivers afterwards took their course. In support of this hypothesis, he shows that, whereas the basin of the Seine is now drained by the one river and its tributaries, the diluvial waters held their course straight across that basin and debouched in five main channels—one, marked by the hills of Montmorency and Satory, took the course of the Seine below Montereau to the sea, but in a more direct and broader line; the second took the course shown by the hills of Villers-Cotterets, thence across the present valley of the Oise, along the valley of the Pays de Bray, to the sea at Dieppe; the third followed in part the course of the Aisne, and then by the line of the Somme valley to the sea; and the fourth and fifth by those of the valleys of the Aulthie and Cauche. M. Belgrand accounts for the rapidity and force of this cataclysm in the belief, which he shares with M. Elie de Beaumont, that the elevation of the Alps took place rapidly and suddenly.

But there was a second elevation of the Alps, at a later geological period, and which, according to M. Belgrand, may have produced a second deluge, not by the displacement of the sea, for then there were only lakes on the north-western side of those mountains, but by the sudden melting of the snow on that great range;

and our author again adopts the views of M. Elie de Beaumont on this subject. The distinguished geologist propounded in 1847 the theory that that last convulsion of the Alps was accompanied by an enormous disengagement of those gases to which has been attributed the formation of the Dolomites and Gypsum beds of that chain, and that this caused the accumulated snows to melt in a very brief period of time (*un instant*). At the same time, according to the same authority, the Pliocene lakes of "La Bresse" were raised and drained. Thus, suggests M. Belgrand, this second convulsion might have caused another diluvial wave to pass over the basin of the Seine—an hypothesis also advanced by M. Elie de Beaumont, who speaks of "the probable concourse in this off-throw flood (*deversement*) towards the north-west, of the waters of the great lake of La Bresse, in the production of the diluvial phenomena observed in the neighborhood of Paris."

We are disposed to agree with our author in the opinion, which we have elsewhere expressed, that the original contour of the surface with its higher valleys and hills, is due to a cause different from that which excavated the present river valleys—that it preceded and is independent of it—but we cannot agree with him as to the nature of that cause. Without going far into the argument, we may mention that the well-known fact of the gravel found in each tributary of the valley of the Seine, consisting of the *debris* of those rocks only through which that tributary flows, while in the Seine valley are found the *debris* of all the tributaries, together with its own and no more, is, it seems to us, a conclusive argument against the passage of a body of water from one great basin to another—against the flow of such a body of water from the Alps across the Jura, the great plains of the Doubs and the Soane, the southern prolongation of the Vosges, and, over the separating water-shed formed by the lower hills of Burgundy, to the Seine basin, and so to sea on the northern shores of France. Such a cataclysm must surely have spread the *debris* of the strata destroyed in its course north-westward along the tract over which it flowed. Some remains of the rocks of Switzerland, of those of the Vosges and of Burgundy, must surely have been detected in the course of its passage. How can the author account for the large blocks and abundant *debris* of the Seine valley—which blocks and *debris* he considers as originally due to this cataclysmic action—and yet overlook the almost necessary consequence of the introduction of some foreign elements into the Seine basin, whereas none such exist? Not only is the *debris* of each great basin restricted to its own rocks, but even each tributary valley has its own special rock *debris* and no other. M. Belgrand remarks, it is true, of the Somme Valley, which lies on the line of his third great diluvial water channel, and which prolonged south-east passes across the Oise Valley and up that of the Aisne, that some *debris* of the older rocks of the latter areas have been found in the chalk valley of the Somme. But we must confess we have never found a trace of such a mixture, and we have particularly examined the Drift of those areas with a with a view to the determination of this point. At the same time the water-shed between the two valleys is so low that their complete separation in old times appears to us more remarkable than their present independence, and we can quite conceive the possibility of the Oise waters, when that river flowed at its higher level, passing at periods of flood into the valley of the Somme, and so carrying some small amount of *debris* across the present water-shed, especially as so good an observer as M. Buteux is referred to as the authority for this fact. If there, however, it is evidently quite the exception, and may be accounted for as just suggested.

With regard to the ingenious suggestion of M. Belgrand, that some south-east and north-west valleys of the table-lands are faced on the opposite side of intersecting river valleys by a bay in the hills due to the violence of the checked diluvial waters, such for example as the amphitheatre in the hills on the west of the River Ecolle between Milly and Moigny and again at Soissy, it is to be remarked that such amphitheatres exist equally on the opposite or lee side of the hills towards La Ferté-Aleps and Maisse; and, further, that, in the same Tertiary area beyond the intersecting range of hills between the Ecolle and the Essonne (which according M. Belgrand's views should have acted as a break-water), the south-east and north-west ridges again resume between the valleys of the Essonne and the Eure.

After the contour of the surface produced by this cataclysm, and by which M. Belgrand considers that all traces of any previous river courses must have been obliterated, the Seine and its tributaries began to flow at an elevation estimated by him at from 80 to 100 ft. above the present level. This he proves, as we have already done, by the occurrence of the remains of land mammalia and of river and land shells in beds of drift at that elevation above the Seine on some of the hills near Paris. This part of M. Belgrand's work is admirably illustrated, both by general and local sections, and contains valuable lists of the mammalian remains, in the determination of which he had the advantage of the high authority of the late M. Ed. Lartet. Here again we cannot, however, agree with him in his *modus operandi.* The great boulders of sandstone, meulière, granite, etc., found in the valley gravel of the Seine, are attributed by M. Belgrand in the first place to removal to the line of the Seine valley by diluvial action, and subsequently to their drifting along the valley channel by the river action during floods of the Quarternary period, and he gives some remarkable instances of the power of water to remove large blocks, and of the rate at which such blocks move. When, however, it is considered that the granitic rocks of the Morvan have been transported some 150 miles, and other rock boulders in proportion; that the angles of many of the large blocks of sandstone and of meulière constantly show little wear, and that they are dispersed irregularly and at various levels, some imbedded in soft clays, and others in sand or fine gravel, and that these latter are often twisted and contorted, we can only explain the phenomena by the action of river ice and transport thereby.

M. Belgrand, on the other hand, shows that a prolonged and steady fall of rain, even if not very heavy, during the winter, now produces great floods—that such rivers as the Yonne and Cure flowing over impermeable strata are subject to sudden and great freshets after a heavy but short fall, whereas the Marne and Seine flowing over permeable strata have their floods retarded, but, at the same time, rendered more permanent by the rainfall having to pass through the strata and delivered in springs. He also shows that when the permeable strata become saturated by long-continued rains, they act as impermeable strata, and that the floods follow close on the rainfall besides being long maintained, so that in the remarkable and long wet winter seasons of 1658 and 1802 the Seine rose at Paris in the one case 29 ft., and in the other 24½ above its ordinary low level, and the floods in the last case lasted three months. M. Belgrand considers that this state of things was a normal condition during the Quaternary period, and he sees reason to believe that the rainfall at that period must have been very much greater than at present.

The ordinary low-water discharge of the Seine at Paris is 75 cubic metres per second; but during these great floods it rose to 2,400 and 2,000 cubic metres. M. Belgrand gives a list of eight such floods in the last two centuries, during which the discharge was above thirty times greater than the ordinary low-water discharge. In rivers flowing over more impermeable strata the difference is still greater; and he mentions that in the Loire at Orleans it has amounted to as much as 400 times, or 25 : 10,000. We may take the width of the Seine valley during the high-level gravel period at six kilometres, and during the low-level gravel period at about two kilometres; and M. Belgrand estimates that the river in flood had in the first instance a sectional area of 60,000 sq. metres, and in the second of 40,000 metres; and, calculating the flow at a given rate per sec., the discharge, as compared with that of the present, would be as under:

Discharge per second of the Seine at Paris in the present period and during floods in past periods:

		Extreme rise of river. Metres.	Discharge of river. Cubic Metres.
Present river	low water	8.81	75
	flood water	....	2,400
Old river during the Quaternary period	low level stage	20	27,000
			to
	high level stage	13	60,000

Large as these Quaternary period quantities are, M. Belgrand thinks that there are cases of recent occurrence to prove that it is possible to realize them. He mentions a flood following on a heavy rainfall in the valley of the Armançon, a small river flowing over impermeable strata, with a basin of only 1,490, sq. kilometres, which had its discharge raised for a short time to 800 cubic metres per second; and he infers that under like conditions of rain and impermeability the Seine, with its basin of 78,600 sq. kilometres, might have its discharge raised to 42,444 cubic metres, showing, that notwithstanding the size of the old river channels, the area drained during a period of greater rainfall would have sufficed for the necessary water supply.

In confirmation of this larger and more permanent supply of water, M. Belgrand instances the presence of the Hippopotamus, the remains of which are found at several places in the Seine basin as well as in that of the Somme, and which would have required for its existence larger and fuller rivers. He also derives a further argument in the presence of this animal, against a prolonged and severe winter cold, which he considers would have been fatal to it. M. Belgrand, nevertheless, argues that the presence of the Reindeer indicates the six summer months temperature of Scandinavia, not exceeding in the mean 8 deg. Centigrade; but with such a summer temperature we hardly see how he can avoid the three months' winter temperature of the same latitude or of 4.6 per cent. A still more extreme winter temperature is in fact indicated by the presence of the Musk Ox and the Marmot. It is to be observed also that that the Reindeer at that time lived as far south as the Pyrenees, and that the physical condition of the drift deposits are, as we have before shown, strictly in accordance with a very low winter temperature. As the Hippopotamus is an extinct species, we do not know how far it may, like the extinct Elephants and Rhinoceroses, have been adapted to live in a severe climate. M. Belgrand's work is full of interesting details of the distribution of these and the other Quaternary animals, not only over the Seine basin, but in some cases over the whole of France. He gives also a monograph with figures, by M. Bourguingnat, of all the mollusca of this age found in the Seine basin. This well-known conchologist makes out that out of a total of 76 there are 38 new species which he considers as extinct, a conclusion which we expect English conchologists will hardly be prepared to agree with, as they have detected no extinct species in these deposits, and find only a few which are not local—a view in which we also believe most French conchologists join. The author considers that the same mammalian fauna is common to both the high-level and the low-level gravels. In one main point, however, do these gravels differ. In those of the high-levels of Montreuil and Bicêtre no human remains, no flint implements, have been found, whereas, in those of the low-levels of Clichy, Grenelle, etc., above 5,000 flints, more or less worked, are stated to have been found by a single collector. Besides these works of early man, M. Belgrand states that human bones, skulls, and entire skeletons, have been found in these lower gravels; but it seems to us that much of this evidence requires confirmation.

The Quaternary period of the Seine basin is coeval, in M. Belgrand's opinion, with the Glacial period, and he considers that it was brought suddenly to a close with the low-level gravels. To this Quaternary period the peat deposits immediately succeed, owing, as the author ingeniously suggests, to the suddenly diminished rainfall leaving the rivers clearer and under conditions favorable for the growth of peat, which he shows never takes place in river valleys subject to frequent and heavy floods, but always in valleys where springs abound, and the floods are few and not turbulent.

The latter part of the work is occupied with a minute account of the formation of gravel beds, and of the position of the organic remains, showing how all the features of those deposits are to be accounted for by ordinary river action, and that the mammalian remains are abundant precisely at those very places where a river with strong currents and numerous eddies would leave them. He endeavors to account also for the fact of all the bones of the larger animals being found in the coarser bottom beds of gravel, by the circumstances that these coarser beds were formed in those deeper water-channels along which only the larger carcases could have floated, and which were afterwards surmounted by those upper beds of sand and finer gravel, which he considers to be due to silting up (*alluvionnement*) of the channel where the river had changed its course to another channel. The brick earth or Loess is ascribed by him, as by English geologists, to river floods. But instead of considering it, as we do, to be produced by successive floods at all the various levels of the river, from the high to the low level, M. Belgrand admits but two levels, the high and the low, and that owing to a sudden elevation of the land, the excavation between these two levels was produced at once without intermediate stages. Consequently, he considers that the height of the Loess above these two levels, marks in each case the rise of the flood waters. This, we think, is a weak point in his argument. According to his view, which he illustrates by a section, showing the range of the Loess up the hill slopes, he concludes that the floods of the low-level stage of the river rose, notwithstanding the width of the valley, to a height of 66 ft., and during the high-level stage, to a height of 43 ft., which give very much larger sectional areas for the river in flood than is otherwise necessary, and such as we conceived the area drained would have been insufficient to fill even with greatly larger rainfall. For, although the discharge of the Armançon may in a particular case of heavy rainfall have been so large as when multiplied by the whole area to give two-thirds of the required supply, still it is perfectly well known that the discharge by the main river never equals the sum of all its tributaries, and the discharge of the Seine at Paris on that occasion actually only rose to 1,250 cubic metres per sec. There are besides, beds of gravel on the slopes of Clichy towards Paris, and again on the slopes leading to Charenton, distinct beds of gravel at intermediate levels, though of limited extent.

Thus, M. Belgrand ascribes the gravel beds and the Loess of the Seine Basin to old river action, referring the red loam alone of the higher plains above to diluvial causes, in opposition to the view usually received in France, according to which all these Drift beds are divided into the three diluvial deposits of *Diluvium gris*, *Diluvium rouge*, and *Limon* or *Loess*. As we have already expressed very similar views respecting the commonly accepted classification, we cordially agree with the author on this point.

The illustrations forming the second volume constitute a very interesting exhibition of the art of Photo-lithography. The execution varies a good deal, and there are plates which, though valuable for their truthfulness, are rather indistinct. Some of the representations of the Flint Implements are excellent. The work is somewhat large and costly ; but as a copious record of facts, an ingenious statement of theory, and a reliable representation of specimens, this work of M. Belgrand will be greatly valued by all those who feel an interest in the remarkable phenomena connected with the present configuration of the country, the distribution of life during the Quaternary period, and especially with the evidence bearing on the Antiquity of Man.

FIELD ARTILLERY.

From "The Engineer."

On the afternoon of Thursday, February 29th, Captain Sladen, R. A., of the Royal Laboratory, read a paper in the theatre of the R. A. Institution on "Flat Trajectories." Captain Sladen is the officer who proposed the 16-pounder gun of 3.3 in. calibre tried in competition with the 3.6 in. 16-pounder. The latter had been previously experimented on, and, eventually recommended by the special committee on muzzle-loading rifled guns of large calibre for field service.

The lecture was well attended. The lecturer commenced by enumerating the advantages of a flat trajectory, viz., accuracy, hard hitting, and covering the ground closely. He illustrated the last mentioned by a comparison of the falling angles of the Martini-Henry and Snider rifle bullets, the former of which in the last 6 ft. of descent travels over 104 yards, the latter only 62 yards of ground, so that these two distances represent the relative defended spaces, or spaces of danger to the enemy's infantry.

The lecturer next remarked on the imperfect investigations frequently made of the form of the trajectory of an artillery projectile. In the case of a small arm rifle bullet the arm is now generally fired with the elevation required for 500 yards, and targets are interposed at every 100 yards interval through which the bullet passes. This method is simple and direct, and the results obtained are matters of fact. With guns, on the other hand, the range due to some fixed number of degrees of elevation is often assumed to be the absolute measure of the flatness of the trajectory. This method of dealing with the question the lecturer considered wholly insufficient, and one which might lead to very erroneous conclusions, especially because the element of time is altogether omitted. The lecturer considered that the clearest way of looking at the matter is to compound the motion of the projectile into the horizontal and vertical directions, when it would be seen that the component which is due to the action of gravity is a simple fraction of the time; in fact the height of the trajectory is four times the square of the time of flight.

This, he remarked, is true in all cases. A ball thrown vertically upwards, and falling to the ground in a second, represents the vertical component of the path of every projectile with a time of flight of one second; for to all intents and purposes all fall at the same velocity. The trajectory, then, of two projectiles, with the same time of flight, will be more or less flat in proportion to the horizontal distance described. On this follows what may be given as the definition of the flatness of a trajectory, viz., "the ratio of its height to the range." Thus it happens that when the two 16-pounder guns tried in competition with each other are assumed to be placed on an equal footing when fired at the same degree of elevation, injustice is done to the 3.3 in. calibre, because, its initial velocity being less, it has for the same degree of elevation as its rival a smaller vertical component, and consequently it does not attain to the same height, and its time of flight is less. No one would argue that a train that travelled eleven miles had a slower rate than a train that travelled twelve, if the former had only eleven minutes for the performance of its work and the latter twelve. Of this nature is the injustice done to the gun with the lower initial velocity when it is assumed that equal angles of elevation give equal heights of trajectory, and ought to give equal ranges. Thus the 3.6 in. calibre has at 2 deg. 5 min. elevation a time of flight of 3.3 sec. against the 3 sec. of the 3.3 in. calibre. Far from having equal heights of trajectory, then, the former gun has one of 43.6 ft. and the latter of only 36 ft., consequently this should form an element in the comparison of the flatness of their trajectories. True conclusions cannot be bassed on the measurement of the ranges due to fixed angles of elevation without reference to their times of flight.

The actual angle of departure, however, is affected by other considerations besides the angle of elevation. Thus, where recoil is entirely checked, there is a tendency to rotation round the trail, and an increase of elevation follows. Hence it might be seen how unfair was the comparison made in one case between the 3.6 in. gun, with the recoil checked, and the 3.3 in. gun when recoiling freely. Again, on the other hand, where recoil is not checked an increased velocity of recoil increases the actual angle of departure. This the lecture illustrated by a diagram, in which the line of departure was drawn, not to the muzzle at the moment of ignition of the powder, but to the muzzle when it has mowed back slightly, as is actually the case when the shell leaves it. This diagram was, in fact, similar to that commonly made in astronomical works to show the effect of aberration of light. For these causes, then, the lecturer considered that the sound method of comparison of the flatness of trajectories would be that of the comparison of the ranges due to equal times of flight.

In passing again to the question of the relative powers of the 16-pounder guns of larger and smaller calibre, the lecturer remarked that the shell of smaller calibre, although, no doubt, starting with a lower velocity and slightly less flat trajectory, had, owing to the decreased surface it opposed to the resistance of the air, actually caught up and beaten its rival at so short a range as 724 yards. This he considered was before it arrived at what might be called an ordinary artillery range. At 1,000 yards it had a superior velocity of 11 ft. per second, at 2,000 of 25 ft. per second, and at 3,000 of 34 ft. per second. Thus at all artillery ranges it hit harder and had a flatter trajectory. Shrapnel would thus be superior in its effect, and the same would be true of its common shell. Yet since this gun had been constructed on the "lines" calculated for its rival, better results still might be looked for if made on lines specially designed for it. The only advantage, the lecturer considered, that could be possibly claimed for the 3.6 in. gun was a slight increase in the interior capacity of its shell. Although it had burnt its charge of 1 lb. 12 oz. of "R. large-grained powder" more completely, it remained to be seen whether the result would be the same if ordinary large-grained "L. G." powder had been employed. Where reduced charges were resorted to, the advantage would be still more in favor of the smaller calibre, which admitted of the vent being placed further forward in the bore.

The lecturer then suggested the trial of a lighter gun with a smaller firing charge, observing that the Prussian heavy field gun was only about the same weight behind team as the English horse artillery, and might be compared with it more justly than with a gun weighing 4½ cwt. heavier. There had been a recent report of an experiment as to the powers of mobility of our own horse artillery in India—made by Major-General Tombs—having been followed by the immediate death of four horses. If true, this showed what a serious matter was the consideration of the weight behind team.

After some preliminary remarks made by the chairman, an animated discusion took place, if the word discussion can be applied to the observations of a number of speakers all advocating the same principles. Thus one officer observed that the smaller shell, with even the same velocity as the larger, would penetrate deeper, owing to its reduced surface of resistance. Another remarked that the gun, being designed specially for reserve artillery, must be expected to be called upon to open fire in the teeth of batteries already in position. Power at long ranges, therefore, was a special recommendation.

The chairman in vain invited officers who were advocates of the larger calibre to speak in its favor. It appeared that no artillery officer could be found ready to advocate that side of the question, and the proceedings were concluded by a complimentary expression of thanks to the lecturer for his paper.

THE PUBLIC WORKS OF PARIS.

From "Engineering."

Among the work included in the duties of the Department above the level of the public thoroughfares, we have spoken of the promenades. Lighting follows next. In 1855 the city of Paris conceded the privilege of gas lighting to a company formed with a capital of £2,200,000, under the title of the Parisian Gas Lighting and Heating Company. In compensation for the monopoly accorded to this company, and which consisted in the exclusive right of establishing and mantaining gas mains beneath the streets and roads, it was undertaken:

1. To reduce the price of gas to 6s. 9½d. per 1,000 cubic ft. for private consumers, and to 3s. 4½d. for public use.

2. To pay an annual tax of £8,000 as rent for the ground occupied by the mains, and a duty of 5.06 pence per 1,000 ft. for all gas burned in the city.

3. To extend the service wherever the administration deemed necessary.

4. And, lastly, to divide all profits with the city when the receipts exceeded 10 per cent. on the capital; to terminate on the 1st January, 1872.

In 1860 the obligations of the company were extended, and in obliging them to lay down 113 miles more mains, they were authorized to increase their capital to £3,360,000, and it was stipulated that the division of profits above 10 per cent. should be made on the total, instead of on the first capital.

In 1870 the city, having serious difficulties with the gas company on the subject of the duty of 5.06 pence per 1,000, wished to improve the lighting of the districts served by the 113 miles of mains above alluded to, and which were but imperfectly lighted, and desiring to enjoy larger benefits from the division of profits, made a new treaty with the company, regulating the duty, and stipulating for a division of the profits since 1869 on all net income beyond £496,000 up to 1887, and from that date beyond £450,000 to the end of the concession.

Recent events have served to reduce the profits due to the city, and it is proposed amongst the new taxes to levy one that will absorb them altogether, so that the existing agreement will have to be modified again. The public lighting in Paris comprises 31,122 gas jets, 596 petroleum oil lights, and 971 colza oil burners. This expense for 1870 amounted to £176,000 This outlay will have—at least temporarily—to be reduced, by diminishing the actual amount of lighting given to the city.

The substitution of jets with large openings for those with narrow ones has alone sufficed to effect a radical reform. The burners have openings equal .023 in., and consumes 4.9 ft. per hour. These give 3 times the light of the old burners with the same amount of gas. The illuminating power is checked each night in 11 test rooms distributed over the different quarters of Paris.

The service of concessions of the thoroughfares has for its chief duty the levying of taxes on the chairs and tables placed in the streets outside cafés, the collection of rents of the small open-air shops, the establishment of kiosks, the maintenance of public urinals and water-closets, and the inspection of public advertisements. The Department of Public Vehicles regulates the service of the cabs and omnibuses.

An agreement made in 1862 conferred on the Compagnie des Petites Voitures for a space of 50 years the exclusive right to establish in the streets vehicles for the conveyance of passengers either by the hour or the course. The following obligations were imposed:

1. To establish at once a stock of 3,500 vehicles, and to increase the same at the rate of 100 vehicles a year.

2. To pay a tax of 1 franc per day per vehicle.

3. To divide with the city all profits above 8 per cent.

4. To maintain efficiently the whole of the material, plant, etc.

5. To divide with the city, at the termination of the concession, the available surplus. This company not having been able to prosper under these conditions, the Government made a decree in 1866, on the occasion of a general strike of the drivers, proclaiming a free trade in public vehicles. Every one was thenceforth at liberty to put in circulation a carriage for public hire, upon the sole condition of paying a tax of 1 franc per day. The company was indemnified for the loss of its privileges by an annual compensation, payable during 47 years.

But the regime of liberty has not profited up to the present; neither the public, the private speculators, nor the old company, which continues without monoopoly the exercise of its industry. An important improvement in the service is expected by the employment of distant counters, on the application of which an inquiry is now being made.

The omnibuses are regulated by a treaty of 1861, conceding for 56 years to a company the exclusive right of circulating on the streets, and stationing on the public way, omnibuses serving for the general transport of passengers. The Government privilege to authorize all other schemes for transport on the public streets, or the establishment of tramways, in reserved.

In exchange for these advantages the company engages to pay to the city for the right of standing on and using the thoroughfares, a sum of £80 per year per vehicle, and the city shares, besides all profits over 8 per cent. on a capital of £1,200,000. The company is also bound to establish new lines and to increase the number of vehicles on existing routes whenever the administration shall require.

Under this treaty the omnibus service has been greatly improved. But the company, which prospered up till 1869, has not paid dividends since, and has applied for authority to increase, by 5 centimes, the rates of fares fixed at 15 centimes.

The tax on vehicles of all classes brought to the city a revenue of £133,-600. The extension of tramways into Paris is being seriously discussed at the present time. Of late years foreign capital has flowed to Paris, and financial societies press forward to execute municipal works. The time appears to have come to study carefully the wants of the city, with a view to establish iron roads as much in the suburbs as in the routes radiating towards the principal localities in the Department and to examine into the question of tramways. Upon the latter the experience gained is most favorable as regards the comfort and convenience of passengers. But horse railroads appear out of the question equally in the narrow streets and on the great thoroughfares of Paris, already crowded to excess. Meantime it is necessary to confine experiments to certain roads presenting special and favorable conditions, and to wait till experience can decide on the advantages and disadvantages of tramways with regard to their influence on the road itself, and their effect on the traffic, and the public should, besides, become used to the new means of transport outside Paris before it is introduced to the interior of the city.

The question of low level roads presents great difficulties They could be only constructed at great cost, and would, instead of desiring to reduce the traffic by relieving the streets of the heavy goods vehicles, only be frequented by passengers in scanty numbers. At the utmost, if such means of circulation were tried, they would only be permissible beneath the most crowded streets. High level roads, which have also been proposed, would be very difficult to establish, and, besides, the purpose they would serve would be extremely limited.

The last division of the service of Public Works in Paris is that of architecture and the fine arts. It includes the maintenance of public buildings, new architectural works, and fine art and historical monuments.

The report of the Chief Engineer of the Department shows what enormous sums have been spent to make Paris what it is, what large amounts must be yearly devoted to the maintenance of the various services, and how difficult it is to reduce these expenses despite the present necessity for so doing. Indeed, the utmost proposed reductions make after all but a small difference in the outlay of the staff.

When by degrees an administration has been led to occupy itself with a thousand objects which were unknown a few years ago, when the beauty and luxury of the city of Paris have grown to a necessity not only for France, but for the world, it is almost impossible to reduce the scale of magnificence which has become familiar. But there are doubtless many small reductions and economies to be effected, and it is to be hoped that the Municipal Council will not fail to effect all possible reform in this direction, while they carefully abstain from touching any of the great attractions and charms of the city.

THE TEMPLE OF DIANA AT EPHESUS.*

From "The Building News."

Most people have heard of those famous Seven Sleepers of Ephesus, who, taking refuge from the persecutions of Diocletian at the close of the third century, fell asleep there, and woke up two centuries afterwards to find a new world and a Christian empire. Scarcely less romantic have been the fortunes of the famous Temple of Diana of Ephesus, one of the seven wonders of the ancient world. Destroyed by an earthquake, and plundered by the Goths in the 3d century of the Christian era, it served as a quarry for the architects of the Byzantine city built at Ephesus, probably in the time of Justinian, till, the appetite for plunder being exhausted, the remnant of its ruins was allowed to silt up silently under the slow but sure action of alluvial deposit. Thus the very site of the world-famous temple was obliterated till British enterprise, piercing through 22 ft. of alluvial deposit, came suddenly on the marble pavement, still strewed with broken columns, capitals, and fragments of sculpture. This discovery, one of the happiest efforts of archæology in our time, is due to the persevering energy and sagacity of Mr. Wood, who, having searched for the site of the temple since 1863, first at his own expense, and subsequently with funds supplied by the trustees of the British Museum, has been rewarded, after long years of toil, by the discovery of the site, which was finally ascertained about this time last year. During the last twelvemonth a large area of the temple has been

*Extract from a letter to the London Times.

cleared to the pavement, and various architectural marbles have been found, more or less mutilated, lying as they had been left by the barbarous despoilers in Byzantine times. The diameter of these columns of the temple being 6 ft., the scale of the architecture is, of course, colossal—exceeding, it is believed, in proportions the celebrated Temple of Jupiter Olympius at Athens, the temple at Branchidæ, and all other extant examples of Greek architecture.

The great weight of the marbles discovered rendered it necessary for Mr. Wood to apply for naval aid, which was supplied by the British Government with that alacrity which has distinguished the Admiralty in the history of our recent archæological expeditions, and which can alone insure the complete success of such arduous enterprises. Her Majesty's ship Caledonia, a grand old iron-clad three-decker, was at once sent to Mr. Wood's assistance, and has been engaged since the beginning of this month at Ephesus and Smyrna in hauling, packing, and shipping the marbles of the temple selected by Mr. Wood for the British Museum. I have been favored with a sight of these huge masses before they were packed. The largest, weighing upwards of 11 tons, is part of a drum of one of the *cœlatæ columnæ* mentioned by Pliny—*i.e.*, columns with figures sculptured on them, of which the temple had thirty-six. Of this bold, striking innovation in Greek architecture there exists, it is believed, no other example except at Ephesus. The relief on this drum appears to represent an assemblage of deities, of whom the only one who can be positively identified is Mercury, the rest being draped female figures. On a stone from a pilaster, corresponding in dimensions to the sculptured drum, is a relief representing Hercules struggling with a draped female figure, and on another fragment of a drum are the lower halves of some seated and standing female figures. This sculpture is very bold and effective as decoration, but wants the ineffable charm and freshness of the frieze of the Parthenon, while in masterly vigor of execution and dramatic force it falls far short of the frieze of the Mausoleum. It is careless and inexact in execution, and has the characteristics which we might expect to find in the Greek sculpture of the Macedonian period, when work was executed rapidly to gratify the vanity of kings, and when an Oriental love of mere mass rather than beauty of design had begun to affect both sculpture and architecture. Allowing for this first disappointment, I own that I gazed with peculiar interest on these relics of those famous columns on which St. Paul must have gazed when he preached against them, but which local fanaticism, aided by local vested interests, preserved in all their splendor for three centuries after his coming.

The architecture of the Temple of Diana is Ionic. Mr. Wood has very properly selected such fragments as will show what the base, the capital, and the order generally were like. Once housed in the British Museum, they will furnish materials out of which, not, perhaps, a complete restoration of the temple, but a new chapter in the history of Greek architecture can be constructed, just as out of the fossil bones of the Megatherium an Owen reconstructs lost types in the animal kingdom.

The stones were very heavy, the mud of Ephesus tenacious, and the weather variable; but the Caledonia's blue-jackets have done their work with an alacrity and good humor characteristic of blue-jackets in these expeditions, and by the end of the week the ship will leave this port with her precious cargo, bound for Malta.

NEW PRUSSIAN RIFLE.

From "The Mechanics' Magazine."

It is stated upon good authority that the German Imperial military authorities have recently come to the conclusion that it is necessary to remodel the service-weapon. The new rifle will neither be a needle gun nor a chassepot, but a compound rifle, combining the best features in detail of all the rifles known and experimented on in recent years. It is admitted that the last war demonstrated the existence of grave defects in the needle gun, notably in its relatively short range, due to the curve of its trajectory, the disproportion between the weights of the projectile and the powder charge, or other causes. It is not proposed to adopt either the Werder or the Vetterlini rifle in lieu of the needle gun; in fact, the model of the new gun is not yet complete. But, the problem being to provide a breechloading arm, of small calibre, easily manageable, and of long range, it is proposed to shorten the barrel, alter the rifling, and diminish the bore.

The consideration of the new cartridge has reached a more advanced stage. It is decided to discard the paper envelope, and adopt the metallic case of brass foil, and also to vary the relations between the bullet and the charge in point of weight. All these modifications will, it is anticipated, have material effects upon the trajectory, the range, and the durability of the new weapon. It is expected that the new arm will be ready for approval at the beginning of the new year, so that a sufficient number may be supplied for experiment in the course of firing during the ensuing summer ; and thereafter several corps will be exercised annually in the use of the new weapon, so that in about four years the whole army will have become familiar therewith, previous to which, for obvious reasons, the new armament will not be generally adopted.

It is announced to be the intention of the authorities at the War Department to have the whole of the old pattern smooth bore 68-pounder guns, now in store at Chatham, converted into rifled guns, a considerable sum being taken for the proposed work in the estimates for the approaching year.

ON TRINKETS AND THEIR MANUFACTURE.

By W. G. LARKINS, Esq.,

From "Journal of the Society of Arts."

The desire for the adornment of the person is one of those curious bonds that unite humanity. It is equally strong at both ends of the human race—the dusky belle of a savage African tribe, who pierces the cartilage of her nose to hang therefrom an uncouth ring of gold, is actuated by, to say the least, no lower motive than that which induces some beauty, nurtured under that civilization upon which we pride ourselves, to pierce the cartilage of her delicate ear, to hang therefrom a pendant of jewels; and the dandy of some Indian village, upon whose brown breast is tattoed the head of the lion, the fierce courage of which he desires to emulate, is about on a level with the swell of our own day of horsey proclivities, who sticks into his scarf an imitation of the head of that animal he would have us think he knows so much about. Vanity and superstition are the two great motives that induce the wearing of ornaments—a harmless vanity—perhaps a superstition that may be pardoned—but vanity and superstition, nevertheless. Out of this universal desire has grown up, as a compensation perhaps, an immense industry, or, I should say, a series of industries, by which thousands are enabled to earn their daily bread; and one can safely say this, that at no other time have articles of trinketry been so easily attainable as at the present time. If a person goes undecorated, it is his or her own fault, for lockets, and very well made ones, too, may be had for one penny. One, in the shape of a book, with a likeness of the Prince and Princess of Wales included, had a great sale a little while ago, its wholesale price being one halfpenny; and some brooches made in Germany are now being sold wholesale at the astounding price of three shillings a gross—a farthing each.

If the universality of the desire for personal ornament is a fact, no less a fact is its antiquity. The earliest records of mankind refer to the trinkets worn at the time; indeed, I am perfectly prepared to believe that, if there ever was a pre-historic man, woman, or child, he, she, or it wore some kind of decoration of the period, considered to enhance the personal attractions of the wearer. It is also worthy of remark that the early forms of personal ornament are retained to this day, and, more than that, they are still the popular forms. The workmanship is better, the skill of the chaser and the engraver enriches them, but the circle, the oval, and the crescent, with the simple knot or tie, are the basis on which the larger portion of manufactured trinketry is formed.

Rings are, perhaps, the oldest form of trinkets,—rings for the fingers, legs, and arms. A ring is used as the outward symbol of the married state, as symbolizing eternity. At a very early period rings were used as a medium of exchange, and are still, I believe, in Western Europe and the East, and as the money of African trades, for whom they are specially made of a mixture of copper and iron, and known as "manillas."

Though I by no means think that the slavish imitation of past productions is a thing to be encouraged, or that it is impossible in the present to produce any article that shall not be as original, as graceful, and artistic as anything that has been produced before, yet I do think that designers would do well to study some of the examples of past times that have been preserved to us. There are numbers of beautiful forms, in the British Museum and elsewhere, that are well worth attention and reproduction.

Mr. J. S. Wright, in his paper on "The Jewellery and Gilt Toy Trades," read before the British Association, says:—

"The chief seat of trade formerly was Derby, where large quantities of common and medium jewellery were produced, Edinburgh and London manufacturing the finest goods. The trade has almost disappeared from the former places, and London now depends mainly upon Birmingham for the supply of articles suitable for the middle classes. Since 1836, the trade may be said to have been in a flourishing condition, but during the last twenty years its progress has been almost marvellous. The discovery of gold in Australia and California, the vastly increased wealth of England and her colonies, together with the desire for personal adornment, have united to give an unparalleled prosperity to this branch of industry, which now, directly and indirectly, affords employment to a larger number of persons than any other trade in Birmingham, whilst its increasing demand for novelties undoubtedly tends to develop in a larger degree the inventive and artistic faculties of a considerable portion of the inhabitants. With the exception of a few machinists (and in very busy seasons the workmen in the gun trade), the jewellers are the best paid of the Birmingham artisans. The rate, of course, varies considerably, but he is a poor workman who can only earn 25s. weekly; 30s. to 50s. may be considered the average of wages. Some obtain much more. Enamellers frequently gain as much as from £3 to £5 weekly. Boys are usually apprenticed at fourteen, when they earn 4s. per week, which is increased annually until they are twenty-one, when they generally receive 10s. or 11s. working, as a rule, from eight to seven, with intervals of an hour and a quarter for dinner, and half an hour for tea. Youths sometimes make a considerable sum by working overtime. It is somewhat singular, and contrary to what might have been expected, that only comparatively few females are employed in this trade; its cleanliness, and the delicate manipulation required, would appear to adapt it especially for women. Two branches only give them employment—one is the "guard-chain," and the other is the ordinary press work, when they cut out or form the "roughs;" but a considerable number indirectly obtain their living in connection with the trade by making paper and leather boxes, which are largely used, not only to protect, but also to set-off the finished article.

"The jewellery trade furnishes a most interesting and important illustration of a peculiarity which places Birmingham in favorable contrast with every other large town and centre of industry in the kingdom—namely, the large number of small but independent manufacturers it supports. There are comparatively few large manufactories, most of the articles for which it is noted being produced in shops where five to fifty hands are employed. Probably nine out of every ten of the master jewellers, who are now carrying on business on their own account, were originally workmen. In one instance, at least, not less than twelve independent concerns are now in active operation, each employing a number of hands, the principals of these twelve concerns having all been employed as apprentices or workmen in a manufactory which itself has been established within twenty-five years.

"All that is needed for a workman to start as a master is a peculiarly-shaped bench and a leather-apron, one or two pounds' worth of tools (including a blow-pipe), and for material a few sovereigns, and some ounces of copper and zinc. His shop may be the top room of his house, or a small building over the washhouse at a rent of 2s. or 2s. 6d. per week, and the indispensable gas jet, which the gas company will supply on credit. With these appliances and a skilful hand, he may produce scarf-pins, studs, links, rings, lockets, etc., for all of which he will find a ready market on the Saturday, among the numerous "factors," whose special business it is to supply the shopkeepers throughout the country.

"The causes thus indicated, which have so largely contributed to the establishment and prosperity of the jewellery trade in Birmingham, would, however, be insufficient of themselves to give it a permanent character. No doubt, success for a time largely contributes to the permanence of a trade; dealers in the various tools, stones, and materials required are drawn together, and this affords great facility to manufacturers, especially to those of small capital. Then the demand for novelty stimulates the ingenuity of the producer, and, by insuring a continued supply of new styles, developes trade. There is no doubt it is the superiority of the workmanship that has continued the trade in its prosperous condition; and it is upon this superiority that reliance may be placed for its further development and permanent establishment in this locality."

FRANCE.

It is generally supposed that the greater quantity of mock jewellery comes from France. This is not the case at the present time. It used to be so, but for the last few years the manufacture has been steadily declining, and I think I may say that, whereas a thousand pounds' worth used to go to Paris for every hundred pounds sent to Birmingham, that now the reverse is the case, and Birmingham takes the thousands, whilst France takes the hundreds. The cause of this is easily divined. The manufacturers of France, with their undoubted artistic skill, cannot compete with our mechanical appliances. The superior machinery that has been erected at Birmingham has brought the trade to us, and it ought to be a matter of congratulation that the progress of our own industry and manufacture is thus meeting with reward. The late unhappy war probably gave the final death-stroke to a manufacture that once was of great proportions. There is also another reason why France cannot compete with Birmingham, and that is this: A manufacturer, having ordered a die, and desiring to try the market with a few samples, has to pay dearly to the die-sinker for them, and is, therefore, unable to put them forward as cheaply as he might, were he able to stamp himself. Of course, if he is able to give an order for some large number, he can do the thing cheaply; but should he run short of a particular pattern, he is unable to supply a small order. In this country, a manufacturer, having his own dies and presses, can do as he pleases, can at once arrive at an approximation of the price it will pay him to sell at. I am afraid that France having once lost the trade, will never recover it. English manufacturers head the cards they affix their articles to with inscriptions in French, and even put French names to them, because of the reputation French jewellery once had; but the largest portion of that so labelled is nearly all made either in London or Birmingham. This reputation it is found convenient to keep up, mostly because French artistic skill is so much higher than British; and although, at the present time, we are beating the French in the manufacture of both real and imitation jewellery, I do not think that in artistic skill we are any way near them. They certainly do turn out some beautiful designs, the result of the better acquaintance of their artist-workmen with works of art and design, and the result of the artistic education they receive. It seems to me, looking at the French trinketry, that they excel more particularly in combinations. It is, perhaps, one of the most difficult things possible to put in harmonious contact a variety of materials, of different colors, in many different ways, so that there shall not be a wearisome sameness. The British workman has, however, been so educated, that when once his mind is set upon producing anything in a certain manner, and his fingers get accustomed to work in a certain way, it is very difficult to get him to alter his manner, and manufacturers find it better worth their while to turn out thousands of an article all of one shape and pattern than to give their workmen a little license to vary and alter. Machinery has, of course, done much to increase this; and if it has cheapened production, it has, to a certain extent, fettered design.

One of the particular branches of manufacture that the French excel in, and we cannot touch, is that of the application of steel. This manufacture originated, I believe, in England, but was adopted by the French, who now supply us with the ornaments, the trade having dropped in England altogether. The steel ornaments are made up of small nails or pins of iron, the heads of which are first of all hardened as steel, then faceted and polished. They are then riveted to the ornament, which is fashioned previously.

GERMANY.

Germany manufactures a considerable quantity of jewellery. The principal exports to this country are very cheap imitations, in the form of ear-rings and brooches, etc. Among the specialties of the German manufacture are the articles made of the garnets of Bohemia. The Bohemian garnets are not of the finest, being somewhat black; still they make an effective ornament. The grinding and polishing of them gives employment to a large number of persons during the summer. When water is frozen in the winter, they are unable to continue the operations; therefore, there are times when it is difficult to obtain this jewellery. The garnets are mounted by the working jewellers of Prague.

Silver filagree is another *specialité* of German export jewellery. Such a bracelet as the one on the table, which displays a large amount of work, it would be almost impossible to produce in England for the same price on account of the dearness of labor. There is some taste in the design. Glass beads, and little glass brooches with a bit of tinsel upon them, find a ready sale in the English market, roughly and coarsely as they are made. The agate ear-rings and brooches sold wholesale at about 7½d. per pair, are ground and polished like the garnets; their chief fault, however, is the mounting. The German workmen have not quite the capabilities of turning out things cheaply and strongly. The characteristics of all German jewellery is that it is, as far as the metal work is concerned, thin and frail.

Vulcanite, to which I shall refer presently, comes principally from Germany. In some things, glass-working, for instance, Germany can excel. Glass beads she makes in large quantities, as well as imitation pearls. The glass ear-rings on the table are sold wholesale in this country at 8d. per dozen pairs. The rococo work, of which there was a large quantity exhibited in last year's exhibition, is another species of ornament.

Ivory carving is another industry which the Germans have turned to account in manufacturing personal ornaments, and they can produce brooches and other things at a very cheap rate.

Some years ago there was a considerable quantity of iron ornaments imported from Berlin, where the manufacture of it by casting forms a large industry. They were sold just as they came from the mould, and had a rapid sale here at the time, and were very effective and delicate in appearance. By great care in the choice of iron, and other precautions, the founders are enabled to obtain the metal in a degree of fluidity necessary to fill the minute and sometimes delicate moulds. The public taste has herein altered, and it is doubtful if any could now be obtained.

MATERIALS.

If the wearing of trinkets is a universal passion, the materials of which those trinkets can be made are almost endless in number, ranging from human hair through the animal, vegetable, and mineral world, down to the granite foundations upon which the world is built. Every metal has had its turn but one, for I have not heard that mercury, in its natural state, has yet been made into a brooch or ring. Various kinds of woods, ivory, bone, hair, pebbles, precious stones, glass, leather, paper, and the shells of mollusks, granite, and plaster, are among those in use at the present day; and what will or will not be turned to account, as the tastes of the public vary, or the ingenuity of manufacturers increase, I cannot say. There is no manufacture that affords a greater range of material, or of opportunities for the display of artistic talent in using it. And when we take into consideration the richness and value of some of the materials, we may say that it affords a grand opportunity for a combination of both value and design.

GOLD.

Gold, of course, is the metal from which the greatest portion of jewellery is made, and, besides its intrinsic value, no metal is so pleasing in appearance, or is so well suited for the purpose. Even when of low standard, it is able to hold its own against other metals; and this being the case, a successful imitation of gold is what the maker of mock jewellery most desires.

While talking of gold of low standard, I may perhaps be allowed to say, as affecting the public very much in this matter of trinkets, that many persons imagine that in buying a gold ring for instance, because it is hall-marked, it must be of good, or, I will say, fine gold—indeed, in some cases, that it is 18-carat gold, which every one knows is the best adapted for manufacturing purposes. But the fact is, a hall-marked trinket may be as low, I believe, as 9-carat gold, that is to say, the greater portion of it is not gold at all, but alloy. Trinkets made of 18, 16, or 14 carats possess a proportionate intrinsic value of their own. They permit of delicate workmanship, while they are hard enough to resist wear; but below that, although the trinket itself may have an artistic value, yet it can hardly be said to be of gold, 12-carat being half gold and half alloy, and 9-carat gold having but little more than a third of the precious metal in its composition. I need not say that 3, 4, and 6-carat gold is practically of but little value. Till the reign of George III., the standard was fixed at 22 carats, then at 18 carats; subsequently exceptions were made, and now only wedding rings are required to be of 22-carat, or what is called guinea gold. Silver, on the contrary, has a fixed standard, and all hall-marked silver is of the same metallic value. I cannot but say that the suggestion which has been made by Mr. Streeter and others, that the public should insist that the jeweller of whom they may buy should insert upon his invoice the value of the gold he sells, is a good one. This would check certain malpractices that undoubtedly do exist, and I am not at all sure but that it would lead to the fixing of one standard, as is the case in France and other countries, and that then the public would get their value for their money, and we should, by means of our superior powers of production, be enabled to increase our exports of jewellery to the Continent, where at present, it is looked upon with considerable disfavor, not on account of its design or manufacture, but because of the doubt which exists as to its precise value.

There is one reason why the fixed standard of gold is of less importance in this country than in others. England, unlike most continental countries, does not possess a distinctive type of jewellery. In France, Belgium, and other countries, there is a national peasant jewellery, which is handed down from generation to generation, and considerable sums of money are expended in the ornaments which are to become heirlooms, and the manufacture of them is an important industry. Now, as peasants, or persons who are unable to form correct estimates of the value of gold from its appearance and weight, would be greatly liable to be imposed upon, and their savings be exchanged for trash, unless some stringent rule were laid down, a mark of purity, which has only one meaning, is an important thing. Every one knows the mark, and to see it upon the article they may desire to purchase is a guarantee to them that they are justified in expending their money upon it. The amount of money thus locked up in France, Holland, Spain, and other countries is enormous. In England, on the contrary, among the great bulk of the people there is no family jewellery. The great houses of the country pride themselves upon their jewels, but a country farmer, who, it may be, cultivates the land his ancestors for hundreds of years back did, would laugh at the idea of family jewellery; his pride would lie in a different direction. This, doubtless, affects our English manufacture to a certain extent, for trinkets are bought to serve their purpose and their time; they are used to-day and thrown away to-morrow. They grow old-fashioned, are discarded, and, if of gold or silver, are sold as old metal. A French peasant woman would as soon think of selling her ear-rings as old metal, because they did not accord with Paris fashions, as she would think of selling herself for a slave. This want of reverence for personal ornaments may have made manufacturers much more careless, both in design and material, than they would otherwise have been.

SILVER.

Silver is used, to a certain extent, in the manufacture of ornaments, but the alloys

I shall presently refer to have beaten it out of the market. At one time, silver chains were very commonly worn, and many a schoolboy who received as a present a silver watch and chain, went back to school with a feeling of considerable pride in the possession of them. Now, it is extremely probable that, with regard to the chain, at all events, he would be very much better pleased with one of Mr. Pyke's Abyssinian Alberts. To see silver chains now is a rarity, except among rustics, and they are very seldom displayed for sale in the shop windows. I must call attention to the beautiful oxidized silver casket upon the table, lent by Mr. Streeter. It is of exquisite pattern and wormanship, and shows what can be done with that method of treating the metal. There is no doubt whatever that it affords an opportunity for treating silver in a unique and artistic manner, and trinkets are made of it, though I have none here tonight to show you. At present the public has not been sufficiently educated to appreciate them, but I believe that before long, as taste in these things improves, a very large industry will arise in connection with the manufacture of oxidized silver articles; the metal is sterling, and wears well; it is capable of elaborate workmanship, and the treatment of it by oxidation gives it a distinctive character above a mere silver ornament. The national brooches and pins, set with various stones and pebbles, and known as Scotch jewellery, is a local industry of some merit, and the style seems very suited to the somewhat barbaric forms of the Scotch national ornaments. The stones used are cairngorms, yellow amethysts, jasper, and agate.

ALUMINIUM AND ITS ALLOYS.

The discovery of the metal aluminium, and the success of the experiments of Deville, Gerhard, and others, by which its production in large quantities was proved possible, had a wonderful effect upon the manufacture of imitation jewellery, inasmuch as it gave the manufacturer a metal which was of as good a color, as workable, but not so expensive, as gold. With regard to the metal aluminium itself, I may refer you to a paper read in 1859 by our Secretary, Mr. Le Neve Foster. It is a very malleable and ductile material, about 4 times lighter than silver, and nearly as light as glass; and, from the properties it possesses, it is capable of being applied to a variety of uses. It has been made into jewellery and ornaments of various kinds, but has never, I think, become popular. Some very beautiful articles have been manufactured from it, and in some respects it has an advantage over silver; it is not affected by the atmosphere, while it works easily under the graver. It is, however, rare to see articles made from it exhibited, though, ten or twelve years ago, buttons, shirt-studs, and brooches might have been bought cheaply in the Lowther Arcade and other places. It is, however, largely used for the mounting of telescopes, opera-glasses, surveying instruments, and spectacle frames, its lightness being of value in such articles; and, though it is admirably suited for the wheels of clocks and watches, I do not find that it is extensively, if at all, used. Although its use as a pure metal for trinkets and ornaments has not been established, yet, as I said just now, it has had a very marked effect upon the manufacture of mock jewellery, from the fact that, with copper, it forms an alloy that in color approaches gold more nearly than any other. The aluminium, when used in small quantities, (the proportion being about 5 per cent. of aluminium and 95 of copper), gives a hardness to copper, rendering it capable of being polished to a high degree, but without destroying its malleability, such an alloy having also the further merit of not being sensibly tarnished by exposure to air. The value of such an alloy as this to the maker of imitation jewellery is at once seen. In order to show this, I have here some pieces of chains, one of which, Mr. Streeter tells me, is 18-carat gold; one, Mr. Pyke says, is of what he calls Abyssinian gold, it being really of such an alloy as that I have referred to; and one which is of a "composition," which, up to the discovery of aluminium, was the nearest approach in color to gold that could be got. The difference in favor of the aluminium bronze, which is its correct title, is evident. The "composition" to which I refer is probably an alloy of copper and zinc, in the proportions of 66 parts of one with 34 parts of the other. Pinchbeck is another alloy of copper and zinc, of which watches and other trinkets were made, but it tarnished rapidly, and was much too dark in color even for 18-carat gold, while the mosaic gold, as the alloy I have mentioned is also called, approaches, when polished, very nearly to the appearance of 9-carat gold, of which a large number of trinkets are made and sold.

DOUBLE D'OR.

I have said that the materials of which trinkets can be made are innumerable. Among those that are in use at the present time, and have been used with success, I may mention *double d'or*, which is a manufacture of French invention, dating from the year 1830, and which is produced as follows:—A plate of copper has a layer of gold placed upon it, the thickness of the gold being as one to eleven of the copper. The two plates are made to adhere by solder, and are then passed through rollers till they have been reduced to the required thickness. Great care has to be exercised to keep the metals from parting. It is evident that an article made from such a plate must have a gold surface, more or less thick, and that it is less likely to suffer from abrasion or wear than gilding, where the deposit is oftentimes very infinitesimal, three pennyworth of gold having been known to cover a gross of livery buttons.

TORTOISE-SHELL AND ITS IMITATIONS.

Tortoise-shell ornaments are well known, and, inlaid or in combination with the precious metals, it forms beautiful trinkets. Some ornaments have been made from what is called artificial tortoise-shell, another French invention. This material was first introduced by M. Pinson, of Paris. It is obtained by melting, at a moderate temperature, gelatine with a small amount of metallic salts, and running the whole into moulds. The peculiar markings and grain of the tortoise-shell is obtained by staining the substance with hydro-sulphate of ammonia. The objects produced, such as bracelets, brooches, combs, and various other fancy articles, are then polished and made ready for sale. Some of them are inlaid with gilt metal or silver, and some very pleasing effects have been produced. An imitation tortoise-shell is also made from horn, which is softened by heat, pressed in a mould, and then rehardened.

SHELL, ETC.

Most trinkets of what is called mother-of-pearl are cut from the shell of the oyster, much in the same way that pearl buttons are made. The shells are imported specially for the purpose, and the portions of them likely to be useful are removed by means of small saws revolving in a lathe. These portions are then split, and rendered equal in thickness by rasping. The various shapes are then cut out, and are finally polished by the use of rotten-stone.

In the Exhibition of 1862, Mr. Harry Emanuel exhibited some ornaments in ivory, which were quite new in style, and there is no doubt whatever that the material is capable of being treated in a most artistic manner. It is semi-transparent, and can be used either with its natural color, or stained and painted, still retaining its natural surface.

The same gentleman also exhibited what he called pink pearl-shell jewellery. The shell was used in combination with other materials. The catalogue of the exhibition says, "that the pearl is cut from a rare shell found in the West Indies, and, from its delicacy of color, it far surpasses the best and purest coral, while its brilliancy equals that of many gems. From its hardness, it is susceptible of a very high degree of polish, and it seems eminently adapted for use in jewellery, for which purpose it has not before been applied." It is a rare material, and there is considerable difficulty in manipulating it; but there is no doubt of its beauty, and that it looks well in combination with other jewellery and with the precious metals.

WOOD.

The ornaments in wood most known in this country are those made in bog-oak, of which large numbers are sold yearly at a very moderate price; not so moderate, however, as to preclude imitation. Side by side on the table is a brooch of bog-oak and a brooch and ear-rings of some hard wood, stained to resemble bog-oak, and looking at them it is difficult to tell which is which. There is a considerable difference in the price, however, the imitation being about five times less than the real. The imitation, however, gets brown in a very short time, while the oak always retains its color.

The bracelets and brooches of wood that are made in Scotland, are first of all turned, and are then highly varnished or enamelled, and colored according to the pattern of some popular tartan. Oddly enough, as it seems to me, there is a considerable export of these goods to France.

JET AND ITS IMITATIONS.

Jet is a very beautiful material, found in the slaty rocks at Whitby, in Yorkshire. It is said to have been worked long before the time of the Danes. It is supposed to be, by Dr. Young, wood in a high state of bituminization. It is a material that makes admirable mourning jewellery, and it has a lustre and brightness which gives it the preference over bog-oak. I understand that Birmingham has taken up the manufacture of jet ornaments, that the various pieces of jet are worked at Whitby by hands in the employ of Birmingham manufacturers, and that the pieces are then sent to Birmingham to be mounted. Ebonite and vulcanite, both a compound of caoutchouc and sulphur, are among the imitations of it; another being a compound formed of a wood powder blackened, moulded, aud hardened by a certain process. A large number of persons in the east-end of London gain a livelihood by the manufacture of vulcanite ornaments. The material is very workable, and not expensive, and women and children can help.

The vitreous imitations of jet are not, to me, particularly successful, but, as a manufacture, the English is better than the French, for this reason. The glass in the French is fastened to the metal backing only by shellac; the consequence is, that a slight blow will cause it to break off, and the heat of a room has been known to separate it. The English glass work is soldered to the metal, the glass having first of all a facing of some kind, and exept under very rough usage, it will wear very well. It is sometimes desirable to effect a combination between glass and metal, as in the case of some kind of buttons for instance, and some common kinds of brooches. The pieces of glass, having been moulded or pinched the required shape, are placed on an iron tray upon which is a metal foil upon which a flux has been previously applied. The tray is than placed in a furnace, and at a certain temperature, the glass and the metal foil fuse together, and enter into such perfect combination that, when broken, the metal and the glass still adhere to each other.

MACHINERY AND HAND LABOR.

I have said that machinery has done much for the cheap and rapid production of jewellery. Of course it is almost impossible that hand-work can be entirely dispensed with, especially if anything like a difficult ornamentation is attempted. Even in the commonest article, say a brooch or a locket, the pin has to be fastned by solder, the hinge has to be affixed, and, in the case of a chain, the fasteners at both ends have to be put on. What machinery can do is this, it can save labor in stamping, and punching, and working mathematically correct, as it always does, it can turn out two parts, as the cases of lockets or the links of a chain, so perfectly true to each other, that no cutting, or filing, or fitting is required. To give you an illustration of this, these two little watch wheels, which Mr. Streeter has given me, are so true to each other, and their cogs are so mathematically correct, that they fit one into the other, and become as it were one piece of metal. These wheels can be cut by thousands, and what is true of the first pattern is true of all the rest, and what is true of the whole wheel, is true of every cog; they can be turned round, fitted hap-hazard, yet are still true. So much for what machinery can do towards saving labor of this kind. No hand-work could possibly produce such a wheel as this in such a time and at such a cost. I believe I am right in saying that this wheel can be produced at a cost of threepence. In the case of trinkets, it can stamp out the parts of a locket so that it shall only require a pin to be inserted in a socket to make its manufacture complete, and this it can do for other things.

Here is a locket which has no handwork whatever, about it; it is stamped out of one piece of metal; it has no hinges; it does not, of course, open, and the back and front are kept together by clamps, which are simply turned over.

It may be interesting, perhaps, if I go regularly through the manufacture of a brooch by hand, as followed by a working jeweller. Mr. E. Stokes has kindly enabled me to show you some of the appearances a plate of metal undergoes before it can come out in its complete form. Here is a plate of metal, and here is a die; this die, as you all, I have no doubt, know, is cut in steel by a class of workmen who are called die-sinkers, but of whose work I need say nothing. The object of the workman is to get a perfect impression of this die upon the plate of metal. To obtain this, he manipulates the metal, and gradually works it down into the die bit by bit. Having worked at it for some little time, it is found necessary to anneal the plate, as it is called, for long continued hammering makes it brittle, and incapable of further extension. It is again heated, and allowed to cool slowly. This operation has to be repeated a number of times, during the process of taking the impression, and its various stages are represented here. This having been accomplished, the next step is to add any other parts that may be necessary, by soldering, and then the whole is placed in what is called "pickle," that is, a hot alkaline solution, which removes the effects of the fire, and then, if of common metal, it is gilt, and the parts that are intended to be bright are burnished.

This taking an impression from a die is done by machinery in precisely the same way, only the press acts instead of the repeated taps of the hammer; the whole piece is not stamped out at once, as many will think, but a portion at a time, and the same annealings take place. I believe I am right in saying that experiments are being made with a view to attaining, by a slow and equal pressure, the power of completing the stamp at one operation. Equal pressure is what is wanted. You will readily understand that, in forcing the metal into the die, it is very likely to be much thinner at the point of pressure than anywhere else. This is the great difficulty, which is not overcome even in hand-work. I may say that in making jewellery there is always a loss of metal in working. In filing, chasing, cutting, etc., the metal flies off in a fine powder; this falls upon the floor, and is carefully preserved, the sweepings of a jeweller's shop often being of great value. The working loss in gold is calculated to be one pennyweight per oz.; therefore, in estimating the price of jewellery, this has to be allowed for. In machine-made work, the liability to loss is greater than in hand-made, because the particles fly off to a greater distance, and are not so easy to collect. This difficulty is got over by placing a glass shade over the machine, which catches the particles and keeps them together.

The cutter by which the star shapes for lockets are cut out revolves at the rate of about 3,000 revolutions per minute. The value of such machine cutting is this, you get all the angles mathematically true, which it is almost impossible to get by hand, and this exactness in geometrical patterns, where the least inequality offends the educated eye, is very great.

I hold in my hand a piece of chain, which is, to my mind, a perfect triumph of machine work. It is a piece of common snake-chain, which may be seen in any jeweller's shop, and in common metal, may, I believe, be bought wholesale at about 4s. 6d. a yard. It is a marvellous piece of ingenuity. Its regularity, its flexibility, and the closeness of its manufacture is wonderful, and I think it may fairly rank amongst the highest productions of machinery. I believe I am right in saying that it is the work of a Mr. Holland, and that he has been able to keep the method of manufacture a secret to himself, and that all the snake-chains of this precise pattern are made by him. Any way, no one has yet been able to discover from an inspection of the chain, in what way it is made; and, pull it to pieces as you will, it defies scrutiny; and, as a distinguished manufacturer said to me the other day, "I have tried over and over again, but have failed, and I believe one might grow gray in trying." Mechanists may be able to give a shrewd guess as to the kind of machinery employed, but the combination they cannot guess. Let us hope that the secret, if it is possessed by Mr. Holland only, will not be lost when he is gone; for the pattern is not only one of the most popular, but certainly is one of the most pretty and useful. It has a few defects; for instance, it is easily snapped in two, and when once snapped it is unmendable, for it is the only pattern in which there is no solder.

If I cannot explain to you the manufacture of the snake-chain of Mr. Holland's invention, I can this, which is technically called a spiral chain. It is hand-made, and consists of two wires, with turned edges—a male and a female wire. These are bound round what is called a spit, the edges being turned towards each other. The elastic character which the finished work has, is caused, it will be readily seen, by there being a space between the edges of the wires. The wider the wire the greater the elasticity. The varying width which this bracelet, for instance, has, is given by the spit, which is wider in the centre than it is at the ends. It will, therefore, puzzle some to know how the skip is removed; this is done by burning. When enough of the wire has been rolled, it is cast, spit and all, into the fire; the wood burns but the metal remains intact. It is an ingenious chain. I am not acquainted with the name of the inventor, but he certainly has enabled some very effective ornaments to be produced. There is another method of getting rid of the spit used in France, and possibly in England. The spit is formed of, metal D'Arcy I believe it is called, an alloy of bismuth and lead, which is fusible in boiling water. The chain is made as before, and the alloy is run out by applying heat.

A considerable saving of labor has been effected by the introduction into the trade of ready-made mountings for stones. These mountings are used, not only for the cheaper, but for the finer kinds of jewellery. The parts that go to make up this ear-ring, for instance, are cut out separately by machinery, and then soldered together. Another invention for the same purpose, by Mr. Ferre, consists of a strip of metal with a serrated edge; this is bent in the shape required, and the teeth are bent over the stones.

Now, by way of conclusion, let me give utterance to an idea that has come into my head with regard to this matter of personal adornment. I am not going to say that makers and sellers of sham jewellery are lowering the morals of the country. I will not say they aid and abet the actual lie of those who would have us believe their brass is gold, and I will not go so far as my friend, Dr. Dresser, who, in a paper read before us last year, asked if the destruction of Pompeii and the woes that have lately fallen upon our neighbors across the Cannel, were not due to their false quantities in decorative art. But I do mind me of a sentence of that quaint divine, Dr. Andrew Fuller, who said that, in the time of Elizabeth, a "lady would as soon have patiently digested a lie as have worn a false pearl." I am afraid this high regard for truth is not characteristic of the present generation. There is, on the contrary, a good deal of show and humbug about even ladies and gentlemen, and "all is not gold that glitters;" and it is possible that mock jewellery, false hair, pretended jewels, and other shams may blunt that keen sense of truth and right which distinguished our Saxon progenitors. At the same time, I am bound to admit that by the rapidity and cheapness of manufacture nowadays, things of beauty are placed before those who would never otherwise enjoy them, and perhaps, after all, as Mr. Wright, in the report I have alluded to says, "There is no valid reason why the factory girl should not display her gilt buckle and brooch of the same design as the golden one worn by the lady of the villa." Art may thus serve the community by cheapening the cost of the beautiful, and afford gratification to the humblest members of society, by superior designs reproduced in the cheapest possible form, and attainable by all.

Before I sit down, I must refer you to the specimens of jewellery upon the table. This case, lent by Mr. Streeter, contains some gold ornaments manufactured by machinery, the design being a *fac-simile* of various leaves of trees, the most delicate fibres being reproduced with a surprising fidelity. This diadem and necklace of entwining ivy is most graceful in design, and seems to me to display a great amount of artistic skill in the workmanship. These trinkets, that I have referred to during the evening, have been lent me by Mr. Silber, of Wood street, who very kindly allowed me to choose from his warehouse the representative ornaments of the French, German and English manufacture. I have taken the best and the commonest of each, and placed them side by side, so that you will be able to compare the workmanship and the designs of each of the great export countries, although they are here more as specimens of peculiar manufacture than that of artistic work.

This case of aluminium bronze ornaments, lent me by Mr. Pyke, who calls it Abyssinian gold, brings very clearly before you the perfection that may be arrived at in the manufacture of jewellery. Independently of the value of the material, the workmanship is of the highest order, and I do not think any praise is too high for the artistic skill displayed. If taken as a representation of this particular branch of English manufacture, I do not think it can be beaten by any other country. It is such work as this that shows how the taste of the public is being gradually educated to the appreciation of beautiful forms. Such magnificent gold ornaments as those of Mr. Streeter are beyond the reach of the poor man, who may, however, have in base metal a very artistic article of adornment. It is this only which redeems "mock" jewellery from the vulgarity which one has learnt to consider as almost inseparable from sham. My best thanks are due to all these gentlemen for their kindness, as also to Mr. Stokes for the dies I have referred to.

ON TESTING THE VALUE OF UNGUENTS.

From the "Annual of the Royal School of Naval Architecture and Marine Engineering.'

In this article it is intended to consider merely the unguents used for machinery, and therefore to confine the attention principally to those qualities which are essential for this purpose.

In testing unguents with a view of ascertaining both their absolute and relative values, it is necessary to fully bear in mind what an unguent really is, the use for which it is employed, and the particular qualities we should especially look for in it. First then, an unguent is some substance a thin film of which is capable of preventing the surfaces of two parts of a machine (working together) from coming into actual contact; next, the use of an unguent is to reduce the resistance due to friction—that is, with an unguent the friction should be less than what it would be were the two surfaces actually working in contact, and of course with the reduction of friction there will be a reduction of the wear and tear of the working parts; another use of an unguent is to assist in conducting away the heat which has been generated by the friction.

The quality of an unguent will depend in a great measure on the fulfilment of the above conditions. That is to say, the substance should possess sufficient viscidity to prevent the film being forced out by the pressure with which the two surfaces are kept together; and not enough viscidity to make the friction either equal to, or greater than, that caused by the surfaces themselves rubbing together. The substance, also, by its flowing away, should be able to take away the heat generated by the friction, and so prevent the temperature of the working parts being increased to an objectionable degree. To accomplish this last it must have sufficient fluidity to flow constantly, though slowly, through the bearings, etc., and also to remove any of the solid matter left on the decomposition or evaporation of any part of the unguent.

There are also other properties of unguents which will affect their quality and relative value—namely, their action, if any, on the material of which the surfaces are composed; the action of the atmosphere on them; and the facility with which they can be used in the instruments, or other means, employed for lubrication.

Another point to be borne in mind is the special purpose for which the unguent is to be employed; for example, a lubricant must generally be obtained which is adapted to the pressure by which the rubbing surfaces are kept together, as under a certain pressure (per unit of surface) the minimum friction will be given with one lubricant, and under another pressure with some other lubricant. In some cases an unguent must be provided suitable for the speed at which the machinery moves, as it has been found that a lubricant which will reduce the friction to a minimum at one speed will not so reduce it at another speed. Again, an unguent must sometimes be chosen to suit the material of which the surfaces are composed; for though, as a rule, the friction of two surfaces rubbing together depends on the unguent, and not on the nature of the material, still, in some cases, it is found that some particular lubricant is more suitable for certain surfaces than any other.

Of the substances fulfilling the conditions above specified, most belong to a class of bodies known as fats or oils, a large number of which are found to possess all the requisite qualities, in a greater or less degree, though some few other substances, such as water, graphite, etc., are occasionally used. These various bodies will, of course, vary in point of importance according to the special purpose for which each is to be employed.

The fats or oils used for lubrication are principally animal fats and vegetable fixed oils. Animal fats, though at ordinary temperatures more or less solid, may be regarded, both on account of their general properties and chemical constitution, as varieties of oil, and we shall therefore include them under the general term of solid oils. There are also animal *oils*, properly so called, as whale oil (commonly called train oil), spermaceti oil, etc. Most animal oils, being of a nature known as fixed oils, may be used for purposes of lubrication; but being generally solid at ordinary temperatures, they are principally employed for lubricating those parts of machines which work at high temperatures, which high temperature is not due to friction, but to some other cause; sometimes to the agent by which the machine works, as for instance, such parts of the steam-engine as the cylinder and slide-valve. The most common of the animal oils are:—Tallow, fat of sheep, oxen, and deer; lard, the fat of hogs; seal oil; whale oil; and spermaceti oil. Vegetable oils are very numerous, and most of them are fluid at the usual temperature, but very few can be used as lubricants, as it is necessary that oils so employed should be only those known as fixed oils, and they must be non-drying as well; the chief of these are olive oil, rape oil, almond oil, colza oil, cocoa-nut oil, and palm oil (the last two oils are soft solids at ordinary temperatures). The oils that are liquid at the usual temperature are used for machinery in general, where the working parts are to be kept at a low temperature, and when, of course, the employment of solid oils would be inadmissible. Mineral oils also are sometimes used as unguents.

In some few cases other bodies are used as lubricants, instead of oils; for example, water has been found to answer the purpose, where metal and wood, or metal and leather, are working together; and graphitte and steatite (the substance known as French chalk) have been lately used as the lubricating matter in steam packing. We may mention, in passing, that soapy unguents (composed of an oil, an alkali, and water) are used for temporary purposes; but as they are not generally used for machinery, we need not again refer to them.

Having briefly noticed the several points to which we must turn our attention with reference to unguents, their properties and qualities, we may now proceed to detail the observations which should be made on, and the means which may be employed for testing these various substances, with a view of ascertaining their values as lubricants.

Two sets of observations may be taken—viz., one on the nature and properties of the oil without the aid of machinery; and the second on the properties and qualities of the oil when practically used on machines. The first set will include the following observations:—The limit of temperature at which the oil ceases to be liquid, the effect of the atmosphere on an exposed thin film of the oil, the effect of the atmosphere on the oil in tanks or cans, and the effect of the oil on iron, brass, etc.; the question of *cost* might also be included under this head, but the consideration of this question must not be separated from the practical value. The second class of tests on the practical use of the oil in machinery should include: the manner in which the surfaces are working together, and the circumstances, in every detail, under which the parts are working; the quantity of oil used in a given time; the friction of the parts while in motion, or the *friction of motion;* and the friction of the parts when commencing to move, or the *friction of rest.*

Now to return to the first series of tests. We have first to note the temperature at which the oil ceases to be liquid, for it is requisite that the oil shall be in this condition at the temperature at which the machinery usually works, and, for machines in general, that will be the ordinary temperature of the atmosphere, for if the oil be not liquid, it is evident that the heat which is required, first to raise its temperature to the melting point, and afterwards to liquefy it, must be generated by the friction; and this heat will be in addition to that usually and unavoidably produced by friction when a liquid oil is used. This additional amount of heat represents, and is equivalent to, so much extra work to be expended in friction, for the useless purpose, so far as the efficiency of the machine is concerned, of melting the lubricant.

Next, with regard to the effect of the atmosphere on an exposed thin film of the oil. It has been previously stated that none but fixed and non-drying oils are used as unguents. By a fixed oil is meant one which is not volatile, or which cannot be obtained by the process of distillation; and by a non-drying oil, one which does not absorb oxygen, and so become hardened; is not liable to volatilization, and of which the more liquid portions do not, as in some oils, decompose and leave the more solid behind. It is evident, therefore, that if an oil were a perfectly fixed oil, and also perfectly non-drying, the atmosphere would have no effect upon it at all; but we know that *no* oil possesses these properties perfectly, from the fact that every oil has some peculiar odor, which proves that some part (probably an exceedingly minute quantity) of it evaporates, and that most oils, known as non-drying, on being exposed to the air for some time, eventually become dry. Therefore, what has really to be observed is the relative degree that oils fall short of being perfectly fixed and non-drying oils.* In making these observations, care should be taken that the oils do not gather dust from the atmosphere, and so interfere with the correctness of the results.

The next point is effect of the atmosphere on oils in tanks or cans. Of course the same effect will be produced as in the case of oils exposed in thin films, only that it will take a very much longer time; it is, therefore, simply a question as to how long the oil will retain its original properties. Again, it has been found that the oils which retain their fluid condition at low temperatures, when kept at a low temperature (near the freezing point of water, according to the description of oil) deposit a substance known as *stearin* or *margarin*, the two principles of which oil consists—viz., *olein*, the more liquid portion, and *stearin* or *margarin*, the more solid portion—becoming separated.

We have now to consider the effect of oils on iron, brass, etc., when in contact with these metals. Oils may act chemically on metals, either by their decomposition, when the metal will combine with one or more of the constituents of the oil then set free, or by having acid properties which will act directly on the metal. The action of an oil on copper or brass may be taken as an example of the former, and the action of certain oils on iron as an example of the latter, for when certain oils are used to protect iron from a moist atmosphere, to prevent oxidation, it has been found that they produce a chemical action on that metal, which is due to the acid properties they possess; but the greatest evil is brought about by the acid properties in oils, when, with iron and brass, or copper, in contact, a galvanic action is set up.

With the best oils very little effect is produced on the metals of which the working parts of machines are composed; therefore, if, after keeping any oils in contact with these metals for some considerable time, any decided action is noticed, such oils should be rejected for lubricants.

We will now proceed to the consideration of the second series of observations, the object of which is to ascertain the more immediate qualities of oils in their practical employment as lubricants. The first point which should be noted is the special purpose for which the lubricant is to be used—that is, the manner in which the parts of a machine are rubbing together; for instance, one part may be revolving within another with a motion either continuous or alternate in direction; or one part may be sliding within the other; or, again, the rubbing parts may be plane surfaces. There are other ways in which parts of machinery may work together, but the above are the principal.

Then the circumstances under which the rubbing surfaces are working should be noted—namely the pressure with which the surfaces are kept together; whether that pressure is uniform, as in ordinary shafting, or whether it is variable, as in cross-head guides, etc.; or if the pressure is suddenly applied at intervals, as in the bearings of a connecting-rod. Next, the speed at which the parts are moving should be observed; whether the speed is uniform or variable; whether the machine has intervals of rest; and with regard to plane surfaces working together, whether these are horizontal, vertical, or inclined.

Such observations as these, combined with those we shall mention presently, may be noted so as to ascertain whether a

* Oils in the process of drying become, first, of the consistency of liquid varnish or gum; and should any oil, after exposure for a moderate time, be found to become adhesive, it is useless as an unguent.

particular oil is adapted to a particular kind of machinery.

With regard to the remaining tests which have to be made—viz., the quantity of oil used in a given time, the friction of motion, and the friction of rest—there have been machines made for the special purpose of accurately ascertaining these points. These machines are usually called oil-testing machines; the working parts with which the oil is tried are generally a bearing of some sort, with a shaft or drum revolving within it, so that the manner in which one part is rubbing on the other cannot be varied. In some machines, however, experiments may be made with various speeds, and under different pressures keeping the surfaces together, and also with a variety of materials in the surfaces themselves. The testing is carried on as follows:—A thermometer is fixed to the bearing in such a manner that the temperature of the rubbing parts is obtained as nearly as possible. The lubricator is so constructed that the quantity of oil which flows into the bearing may be easily measured, means being taken also to vary the quantity supplied if necessary. To measure the friction, the whole or part of the bearing which is experimented on is free to revolve (within certain limits) with the shaft. It is carefully adjusted so as to be in equilibrium when the shaft is at rest, and when the shaft is revolving the friction will, of course, have a tendency to move the bearing round with the shaft, but this tendency to move is counteracted and the friction measured by a weight on the bearing acting in the opposite direction. This weight is made capable of being moved towards or from the centre of the shaft, so as to accurately balance the friction, and therefore measure force due to friction with the greatest nicety. Both the *friction of motion* and the *friction of rest* can be ascertained by this means. The results obtained from an oil-testing machine of proper construction are reliable, and therefore very valuable, although it must be borne in mind that these results are obtained only for a shaft revolving in a bearing; still, at the same time we must not forget that a large proportion of the working parts of most machinery consists of revolving shafts. However, if it is required to make further observations with parts working with different motions, or if trials have to be made where an oil-testing machine is not attainable, recourse may be had to machinery in general.

In trying oils on machinery in general, we must first select general bearings, or other working parts on which to make the experiments. The experiments may then be conducted in two ways: first, just sufficient oil should be used to prevent, if possible, the temperature of the working parts from rising too high, and the quantity should be accurately and periodically noted; the temperature also of the rubbing surfaces should be recorded at regular intervals; for the rise of temperature due to friction will be nearly proportional to the friction itself, and where the absolute friction cannot be measured, as is done by an oil-testing machine, the rise of temperature will be sufficiently approximate to show the relative values of the friction with the use of the various oils on trial. Secondly, the experiment may be conducted in this way: let a constant minimum quantity of each oil under trial be used in a unit of time, in turn on the same working parts, and note the rise of temperature in a certain interval of time in each case; for it has been already stated the rise of temperature will be *nearly* proportional to the friction. We say *nearly*, for although the heat given out by friction is exactly a *measure* of the friction itself, the temperature is not quite a measure of the heat. A more extensive and thorough practical trial of oils might be made in factories, with large engines, etc., where it is proposed to use any of them for machinery generally in this way. Let each oil to be tried be used in lubricating the entire plant of machinery for a definite period, noting the quantity used; and during that period take indicator diagrams of the driving engine, as frequently as necessary, to obtain the average power developed; note also the consumption of coal, or, what would be more accurate, the quantity of water evaporated by the boiler. Care should be taken too, that, as far as practicable, the amount of useful work done by the machinery should be exactly alike on all the trials, and this would be possible in many cases. Then, under such circumstances, the only work that will vary is that required to overcome the resistance due to friction, and the difference in the gross power developed by the driving engine will show the variation in the friction. One or two trials of about two or three months' duration, with each kind of oil, would be a fair practical test. In conducting these trials with oils, ample time should be given for making all observations as complete as possible.

Lastly, with regard to the money value of oils. The question of first cost of oils will always be considered as a very important one, especially in large establishments where an immense quantity is used; but at the same time due consideration must be paid to the quantity required, and to the friction of the machinery when using these oils, bearing in mind that increased friction means increased wear and tear of machinery, and an increase of power for driving; or, in other words, an increase in cost of repairs and consumption of fuel. For instance, take the case of olive oil, which, though somewhat expensive, has been found to possess all the qualities required of an unguent, and to answer admirably for nearly all the purposes of lubrication. Suppose we wish to compare with it a cheaper oil (care being taken that we have *pure* olive oil, for it is sometimes adulterated with poppy oil, which is a drying oil, like linseed); after a fair trial with both oils, we *may* find that against a supposed saving with the cheap oil we have to compare the following items: a larger quantity of the cheaper oil consumed; additional outlay for repairs; a larger consumption of fuel, and perhaps also more labor to keep the machinery, etc., clean. And this greater expense in producing useful work may more than counterbalance the apparent saving in using the cheap oil, thus verifying the old proverb that "the dearest is sometimes the cheapest in the long run."

ON THE FUNDAMENTAL PRINCIPLE OF THE ACTION OF A PROPELLER.

From "The Annual of the Royal School of Naval Architecture and Marine Engineering."

The action of a propeller would be a question of considerable interest considered simply as a problem in theoretical mechanics, and its important practical applications render some knowledge of it indispensable to the Naval Architect and Marine Engineer. No one can have attempted to design or improve a propeller without having in his mind some idea of the mode of operation of a propelling instrument, and of the conditions of maximum efficiency to which it is subject. Yet it is only within the last few years that such knowledge has assumed such a definite form and been founded on such definite and widely-received principles, as to be entitled to the name and position of a theory. Even now the question is sometimes regarded as a very difficult one, incapable of treatment without a formidable array of mathematical symbols, so far as it is capable of treatment at all.

Unquestionably the problem has its difficulties, some of which have as yet been but imperfectly overcome, but we believe that the progress which has been made in its solution has been mainly due to the recognition of a principle in mechanics not more difficult to understand and apply than that principle familiarly known as the "Principle of Work," with which all engaged in practical work are so well acquainted. Inasmuch as M. Brin has recently called attention to the subject of propellers in a paper read at the last meeting of the Institution of Naval Architects, we have thought it might interest some readers of the "Annual," if we attempted to explain, in a manner as far as possible divested of mathematical forms and unfamiliar expressions, the principle alluded to, and to trace, as far as the limits of an article admit, its more important applications to the theory of propulsion. We shall do this by drawing a paralled between this principle and the principle of work, explaining step by step the analogies which exist between the two, and the differences which separate them, causing sometimes one and sometimes the other to be the more convenient in application. To thoughtful students of the orginal papers* little that we say will be new, yet perhaps even such may not be sorry to

* We refer especially to the "Mechanical Action of Propellers," by Professor Rankine, and to "Apparent Negative Slip," by Mr. Froude, read before the Institution of Naval Architects in 1865 and 1867 respectively.

see the question restated in a somewhat different form.

ELEMENTARY PRINCIPLES.

To commence at the beginning, let us first take the case of a body moving from rest in a straight line under the action of a constant force in that line, then we know that if P be that force, v the velocity of the body at the end of time t,

$$P\,t = m\,v,$$

where m is a constant, called the "mass" of the body, depending, first, on the size, secondly, on the density of the body, while the product $m\,v$ is called the momentum of the body. Thus the force multiplied by the *time during* which it acts is equal to the momentum of the body ; and if the body have initially a given velocity, then we have only to substitute "change of momentum" for momentum.

But, further, we know that, if x be the space described, we have similarly

$$P\,x = \tfrac{1}{2}\,m\,v^2,$$

so that the force multiplied by the *space through* which it acts is equal to half the mass multiplied by the square of the velocity, or, as we commonly say, to half the vis viva of the body, while if the body have initially a given velocity, we say that the change in the half vis viva is equal to the above-mentioned product.

In the simple case, then, of a force acting on a body moving in its direction we see that the mechanical effect of a force may be measured in two ways: if it be considered as acting *through space* its measure is the change produced in the half vis viva of the body on which it acts, while if it be considered as acting *during time* its measure is the change in the momentum of the body which has been produced in the time. And these two ways of measuring force are not independent, but mutually convertible, the above equations being connected by the relation $x = \frac{1}{2}\,v\,t$—necessarily true whenever a point moves with uniformly increasing velocity quite irrespectively of any consideration of the cause of that motion—by means of which either of these equations may be deduced from the other.

In modern scientific works, forces are measured by the velocities they generate in bodies of given mass, but in practice forces are measured by units of weight such as pounds, so that the product Px to which the familiar name of "work" belongs is measured in foot-pounds or foot-tons. Hence the force P is said to accumulate in the body on which it acts Px foot-pounds of mechanical work which is stored up in the form of vis viva and reproduced again whenever the body is reduced to rest.

Now we have no similar name for the product $P\,t$, but we see at once that it depends on *time* and force just as $P\,x$ depends on *space* and force; hence it is properly measured in second-pounds or second-tons, and we may now say that the force P accumulates $P\,t$ second-pounds of momentum in the body, all which must again be reproduced whenever the body is reduced to rest. If we had a name* for Pt the analogy would be perfect, and in fact the two cases are precisely parallel; for instance, just as we speak of $\frac{2\,g}{v^2}$ as the "height due to the velocity v," so we may with propriety—since

$$P\,t = W\,\frac{v}{g} \text{— call } \frac{v}{g}$$

the time due to the velocity v. And this analogy suggests that if we dwell too exclusively on the *space-effect* of force we may overlook important results obtainable by considering the *time-effect* of force. Following out this idea, let us now generalize, commencing with the

PRINCIPLE OF WORK.

Let us suppose any number of particles connected together in any way and acted on by any forces acting in any directions, then the work done by those forces as the particles move from one set of positions to another is spent in two ways: (1) in changing the half vis viva of the particles, (2) in overcoming their mutual actions. The half vis viva of the particles is simply the sum of the products formed by multiplying the mass of each particle by the half square of its velocity estimated *without reference to direction,* while the way in which work is spent in overcoming mutual actions is easily understood by imagining, the particles connected by elastic strings in which case it is plain that the work done in stretching the strings must be

*Sir W. Thomson has called the $\int Pdt$ "the time integral", but this name is not very suitable for our purpose. For want of a name we are frequently obliged to use the word "force" where we really mean the "time integral," or else to restrict ourselves to the change which occurs in a unit of time.

considered as part of the effect produced by the work done by the external forces. In two cases—namely, that of a rigid body and that of a perfect incompressible and frictionless fluid—this second part does not exist, and the work done by the external forces is equal to the change in the half vis viva. In an actual fluid the present state of our knowledge respecting molecular action hardly permits us to say whether the work dissipated in "friction and shock" should be placed wholly in the first or partly also in the second class; we only know that the work done by the external forces must be equal to the half vis viva due to *visible* motions together with the work dissipated as above. This is the principle of work as applied in hydrodynamics, a principle of wide and well-known application; there is, however, this obstacle to its use—namely, that the amount of work dissipated in friction and shock is usually large and difficult to estimate. Thus the greater part of a work on hydraulics is taken up with the discussion of the "loss of head" by resistances of various kinds, a loss about which little is known except through direct experiment. In the theory of propulsion this obstacle is so serious that little or no progress has been made with the question by aid of the principle of work alone. Let us, therefore, now try and generalize our other principle, which we may call the

PRINCIPLE OF MOMENTUM.

First suppose a particle moving in any way under the action of a force constant in magnitude and direction, then the ordinary laws of motion tell us that the change of momentum *in the direction of the force* is equal to the product of the force and the time—that is, momentum, instead of being estimated like vis viva, irrespectively of direction, must always be estimated in the direction of the force we are considering. Next imagine two particles A and B connected together in any way, and acted on by a pair of forces constant in magnitude and direction; then since "Action and Reaction are equal and opposite," with whatsoever force A draws B in any direction, B will draw A in exactly the opposite, and hence it is easily conceived that whatever momentumthe mutual action of the particles generates in A in any direction, it will generate an exactly equal amount in the opposite direction in B, so that, if we understand by the accumulated momentum in any direction the sum of the momenta of A and B when moving in the same sense, and the difference when moving in the opposite sense, then that accumulated momentum is unaltered by mutual action, and is consequently equal to the product of the sum of the two forces and the time elapsed. And what is true of two forces acting on two particles is true of any set of particles whatever, connected in any way, and acted on by any forces ; the accumulated momentum in any direction is always independent of mutual action, and if the forces have a constant resultant in any direction, the change in that accumulated momentum in any time is equal to the product of that resultant by that time. Conversely, if we observe that a certain change in the accumulated momentum of a system takes place in a given time, we infer just as certainly that a corresponding force must have operated to produce that change, as, when a certain change is observed in the vis viva of a system, we infer that a corresponding amount of work must have been done to effect that change. Such is the principle of momentum stated in a simple form suited to the problems we are about to consider, and its advantages are, (1) that it is true, irrespectively of mutual action ; (2) that we do not require to know the motions of the particles completely, but only their resolved parts in a given direction. On the other hand, we must, in applying the principle, take care to consider all the forces which act on the system, and not merely *those which do work*, as in the case of the principle of work ; for this reason, amongst others, this principle is not nearly so fruitful of important results in the greater number of mechanical problems as the principle of work; it is chiefly in hydrodynamical problems that it is of great value, and it must always be remembered that, so far from the principle being contradictory to the principle of work, on the contrary, the principle of work is frequently deduced from it in works on theoretical dynamics.*

* In his third corollary to his laws of motion, Newton explains what is to be understood by the total momentum of a system, and proves that it is independent of mutual actions. When the principle of the text is generalized by adapting it to the case of variable forces, and extending to couples, we obtain the six general equations which are placed at the commencement of modern works on the dynamics of a system of particles, and which simply express the equality which exists

Now the importance of the principle in hydrodynamics arises from the following considerations:—

It was explained above, that in estimating the total momentum of a system we must take into account the direction of motion of each of the moving particles, and hence it appears that if two equal particles move in opposite directions their total momentum is zero. Now cases of fluid motion are common in which for every particle moving in a given direction with a given velocity another equal particle exists, moving in exactly the opposite direction with that same velocity ; this, for example, is the case in a complete wave length of a deep water rolling wave and in many other kinds of wave motion; it is also so when a fluid forms a whirlpool about a fixed axis; and thus it comes to pass that the resultant momentum of a fluid is often small, while its vis viva is great. And hence, whatever be the true nature of the process by which work is dissipated in a fluid by "shock," whether it be wholly due to infinitesimal whirlpools, or in part to some kind of mutual action between the particles, there can be little doubt that in estimating the momentum of a fluid mass we need only concern ourselves with the *visible* motions generated in the water without attempting to estimate those *invisible* motions which elude our senses, and the effects of which can only be obtained empirically.

We now proceed to examples, and our first example shall be that of a

JET OF WATER STRIKING A PLANE.

A jet of water strikes perpendicularly a plane of indefinite extent, what is the pressure on the plane?

If we follow the course of any particle, at first it is moving perpendicularly to the plane with velocity v (say), then it gradually diverges from the axis of the jet, and at length after the lapse of an unknown time, moves parallel to the plane—that is, its momentum perpendicularly to the plane gradually diminishes, and at length vanishes altogether. Let us now consider the change which takes place in the whole jet in a second; the number and velocity of the particles which at any instant are having their motion gradually changed are always the same, and the change, therefore, consists in the destruction of the momentum perpendicular to the plane of the quantity of water delivered by the jet in 1 sec. Multiply, therefore, the mass of a cubic ft. of water by the delivery in cubic ft. per 1 sec., and that again by v, the result will be the change of momentum in 1 sec., which, in conformity with our principle, must be the pressure on the plane. The result just obtained can also be derived from the principle of work, if the fluid be supposed frictionless, by an artifice which we have not space to point out, but we here see that it is equally true of a fluid with friction, the only supposition made being that the velocity of the fluid perpendicularly to the plane is wholly destroyed—that is, that nothing of the nature of a rebound takes place from the plane. This problem, which is of primary importance in the theory of hydraulic machines, will be found further developed in Rankine's "Steam Engine." We regret that our space will not permit us to give some examples of analogous problems,* many of which are of much interest; but as we are especially considering the theory of propellers, we pass on to questions more nearly concerning that theory; first, however, remarking that the above result has been tested by experiment and found to agree well with theoretical conclusions.†

VESSEL MOVING THROUGH THE WATER.

When a vessel is towed through the water by a rope, the tension of which is R, the work done by R in moving through a space x is R x, and this work is expended in producing visible motions in the water, due to adhesion, friction, or normal pressure, together with certain eddying motions, wholly or partly invisible, due to friction or improper formation of the vessel's surface. These two kinds of motion, together with any change in the motion of the vessel itself, represent a vis viva exactly equivalent to the work done by R.

between the rate of change of the momentum of the system and the impressed forces considered as acting along and about three given axes.

The couple form of the principle is useful in the theory of turbines, as Professor Rankine has shown in his work on the "Steam Engine and other Prime Movers"

* The formulæ placed by M. Brin at the head of his paper on the jet propeller can readily be obtained, but we do not insert them, as the problem of the jet propeller is so easily solved otherwise, and complex formulæ appear to us simply to divert attention from the real difficulties of the question.

† Many different experiments have been made, which will be found fully discussed in "Ruhlmann's Hydraulics," Leipsic, 1857.

Let us now suppose the vessel floating in a sea of finite extent, and let the tension of the rope act during a time t, then, if the resultant horizontal pressure of the finite boundaries of the sea be P, we must have (R—P) t as the momentum accumulated in sea and vessel during this time, for the only horizontal forces acting on the dynamical system are these two—namely, R and P. Now, though the assumption is not as obvious as it appears at first sight, we may assume with considerable probability that if the sea be of infinite extent, P=O, as it would be if all were at rest, and we shall then have Rt as the momentum accumulated in time t, just as R x was the vis viva accumulated through the space x. It may be asked whether this conclusion be true for an imperfect fluid, and the answer appears to be in the affirmative, only the "stiffer" the fluid the greater must be the sea to make the supposition P=O sufficiently approximate, so that in the limiting case of a solid body no extent of body, how great soever, is sufficient to make this hypothesis true. We therefore conclude *that the tension of the rope must be equal to the momentum generated in the sea and vessel during a unit of time.* To take an example: if a vessel of 8,000 tons displacement be towed by a rope the tension of which is 20 tons, the momentum generated at the end of 10 min. is 12,000 second-tons; if the vessel be moving uniformly, this amount of momentum is accummulated in the sea; if, on the contrary, it be initially at rest, and at the end of the 10 min. be moving at 10 ft. per 1 sec., then $\frac{8.000}{g} \times 10$ second-tons has been generated in the vessel, and there remains $12,000 - \frac{8,000}{g} \times 10$, say 9,500 second-tons, which has been generated in the sea. As has been previously stated, there is reason to believe that the momentum spoken of is represented simply by the visible motions of the water, and not also by those invisible motions which must be considered in applying the principle of work.

We need hardly say that we are not hereby enabled to find out what is the actual motion of each particle of water, nor how much water is affected by the passage of the ship. To obtain definite results from the principle of momentum, it is always necessary to know the initial and final motions of the water in some definite direction, and besides that, the quantity of water operated on must be known directly or indirectly.

If the vessel, instead of being towed, be propelled by paddles, screw, or other motor, worked by forces within the vessel itself, the momentum generated in sea and vessel is necessarily and always zero, and any forward momentum generated by the passage of the ship is necessarily exactly balanced by backward momentum generated by action of the propeller.

JET PROPELLER.—MAXIMUM EFFICIENCY OF ANY PROPELLER OPERATING ON UNDISTURBED WATER.

The simplest kind of propeller is known as the jet propeller, that kind of propeller in which the water is drawn from the sea by a centrifugal pump, and projected sternwards from orifices in the side of the vessel.

Here the water operated on is originally at rest; it is drawn into the ship and thereby caused to move with the velocity v, the speed of the ship, and is then projected sternwards out of the orifices with a velocity v, which we will suppose known. The real final velocity of the water is then evidently v—v, and if A be the joint sectional area of the orifices, A v is the quantity of water in cubic ft. per 1 sec. which passes through the orifices, and accordingly, if m be the mass of a cubic ft. of water, m A v (v—v) is the momentum accumulated every 1 sec. in water originally at rest. This can no more be done without the operation of a suitable sternward force than the corresponding amount of accumulated vis viva in the water can be generated without doing an equivalent amount of work, hence it follows that if P be that sternward force,

$$P = m\,A\,v\,(v - \mathrm{v}).$$

To understand how this sternward force exerted on the water operates, let us suppose first that, if the pump was not working, the water in the neighborhood of the orifices would be at rest, or, in other words, that the propeller operates on undisturbed water, then that sternward force operates *solely* through the sides of the passages which conduct the water from the orifices of entry to the orifices of discharge, for the external surface of the vessel will in this case most probably have no sensible influence on the motion of the water, and therefore cannot exert any force on it. It is only the resultant sternward force which is above determined, and not the intensity of that force at any proposed point; it can, however, be seen without much difficulty that near the orifices of entry it is a forward force gradually urging the water forwards from its state of rest till at length it attains the velocity of the ship, while as the water approaches the orifices of discharge it becomes a sternward force, increasing the velocity of the water till finally it is projected from the orifices with velocity v. The difference between the sternward and forward forces is the resultant sternward force P, the magnitude of which has just been determined. In the case spoken of, when the propeller operates on undisturbed water, this force P must be exactly equal to the resistance of the ship, unless, indeed, the ship be not moving uniformly. Hence, if R be that resistance, it follows that

$$R = m A v (v - \text{v}).$$

Our result is independent of the nature and position of the orifices of entry, but we ought not to infer that these are matters of no importance. If these orifices are not so contrived as to admit the water without sensible shock, more water will be set in motion than actually enters the ship, a result equivalent to increasing the resistance of the ship; while if those orifices be placed at a point where the water is considerably disturbed by the passage of the ship, a complex effect is produced, which will be further referred to presently. Meanwhile we go on to consider what conclusions may be drawn from the result just obtained.

The velocity with which the water leaves the ship, is $v - \text{v}$, and the half vis viva accumulated in it is, therefore, $\frac{1}{2} m A v (v - \text{v})^2$; if we add to this the useful work done in propelling the ship, we shall have $R \text{v} + \frac{1}{2} m A v (v - \text{v})^2$, which is equal to $\frac{1}{2} m A v (v^2 - \text{v}^2)$; and this must be the work done by the engines in a unit of time, irrespectively of friction and resistance of the water to being forced through the passages. Accordingly the efficiency of this propeller is $\frac{R \text{v}}{\frac{1}{2} m A v (v^2 - \text{v}^2)}$ that is $\frac{2 \text{v}}{v + \text{v}}$.

It is not difficult to perceive that this result applies to many other cases, and is, in fact, the maximum efficiency attainable by any propeller which operates in undisturbed water, for it was explained above that the propeller must necessarily generate a backward momentum equal to the resistance of the ship, while it is evident that the vis viva of the water proceeding from the propeller is wholly wasted; but that vis viva is obviously least for a given sternward velocity when the water is projected directly sternwards; accordingly if we neglect resistance of passages and friction, the jet propeller is a propeller of maximum efficiency; and, further, the efficiency of any propeller which operates on undisturbed water, and projects it sternwards with velocity v, must be as above $\frac{2 \text{v}}{v + v}$, supposing always that no power is wasted in any other way than in giving motion to the propeller race.

From this result we see that the efficiency approaches unity the nearer v approaches v, while referring to the formula $R = m A v (v - \text{v})$, we see that, the smaller $v - \text{v}$ is, the greater must be A, and hence we conclude that, other things being equal, the efficiency of a propeller is greater the greater the quantity of water on which it operates. We shall have occasion to mention this hereafter.

Our space will not permit us to discuss the case where the water operated on is disturbed by the passage of the ship, and we besides do not wish in the present article to enter on questions which are not as yet completely understood. We merely remark in passing, that it is believed that in most cases the efficiency of a propeller is reduced by this cause. M. Brin, indeed, maintains in the paper above alluded to that the efficiency of the jet propeller can be made unity by placing the orifices of entry at the stern. This, however, does not seem possible, for to realize a propeller of efficiency unity we must take all the water set permanently in motion by the ship, and must project it backwards with such a velocity as to reduce it to rest. It is evident that if the ship and propeller together leave behind it any water possessing permanent motion, then all the accumulated work in that water will be wasted. The reasoning by which M. Brin obtains his result does not depend on any consideration of disturbed water, but appears to assume that the pressure at the orifices of entry can never be less than the hydrostatic pressure due to the depth of the orifices, an assumption which amounts to supposing that no force is required to draw the water into the ship. In the other cases M. Brin* makes no similar assumption, and hence has arrived at a result agreeing with ours. We are certainly disposed to believe that the obvious view of the subject is the true one—namely, that the stern is the most unfavorable position for the orifices, but to give reasons would require a long discussion.

Some of the results of this section can be obtained by the principle of work alone, but we have not space to give the reasoning We now pass on to

FEATHERING PADDLES.

We have already said that the principle of momentum will not produce definite results unless we know independently the initial motion of the water, the final motion of the water, and the quantity of water operated on. For these data we must have recourse to observation in every case. In feathering paddles the obvious phenomena are the great streams of water issuing from the paddles. Initially this water is at rest, while finally it moves as is usually supposed with a velocity (v) equal to that of the paddle-floats, an assumption which apparently cannot be far from the truth. If, then, $Q=A\ v$ be the quantity of water operated on per 1 sec., the momentum accumulated in the streams in every second must be $m\ Q\ (v—\mathrm{v})$, which again, assuming that the water amidships would be at rest if the paddles were not working, must be equal to the resistance (R) of the ship. Moreover, the half vis viva of the streams will be $\frac{1}{2}\ m\ Q\ (v—\mathrm{v})^2$, and is consequently equal to $\frac{1}{2}$ R $(v—\mathrm{v})$. Now the useful work done per 1 sec. is R v, and the power exerted by the engines, irrespectively of friction and other resistances to be mentioned presently, is R v, whence the power wasted is R $(v—\mathrm{v})$. Thus we see that the power wasted in producing that motion in the water which is necessary in order to obtain the required propelling reaction is only one-half the whole waste, a result characteristic of all propellers operating on the water with uniform velocity. One condition of maximum efficiency in a propeller is the same as that in any other hydraulic machine—namely, that during entrance to and the whole passage of the water through the machine, there should be as little "shock" as possible, a condition which is violated by paddles, as is shown by the violent dashing about which the water undergoes under their action. Our investigation shows that this "churning" absorbs as much work as is required to obtain the propelling reaction; and, in fact, more than as much is thus absorbed, for we have neglected the resistance to forcing the floats in and out of the water, a process giving rise to vertical forces not taken into account in the preceding investigation, but which increase the work done by the engines, so that the efficiency of paddles is somewhat less than $\frac{\mathrm{v}}{v}$.

It may now be of some interest to compare roughly the efficiency of the jet propeller and feathering paddles, and for this purpose we shall suppose that the great technical difficulties which would arise from the use of large orifices have been overcome, so that our jet propeller sends back the same quantity of water with the same velocity as feathering paddles of 20 per cent. slip, for which the orifices must be somewhere about the same size as the paddle-floats. Then the power wasted by the paddles will be 10 per cent. in the race, and from 25 to 30 per cent. in "churning" the water and engine friction, while the jet propeller will waste 10 per cent. in the race, and at least 35 per cent. in engine friction and resistance of passages. Though it is generally agreed that the jet propeller has not yet been tried under favorable circumstances, we imagine most of our readers will agree with us in thinking 35 per cent. a low estimate. But it will be seen that even thus the jet propeller is not so efficient as paddles, while in practice the jet area must be reduced, when, as shown above, the comparison becomes yet more unfavorable. Besides the practical difficulties in the way of large orifices there is this objection, that if the orifices of discharge be placed under water they will add greatly to the resistance of the ship, while if they are placed clear of

* M. Brin's reasoning is not always easy to follow, but if the reader compares Section 7 of this Memoir with the mode by which he deduces equation (9) of Section 5 from equation (8) of the same section, it will be seen, we think, that something like this is assumed.

the water, work must be done to raise the water passing through them above the sea level; with large orifices the work so spent would be a very considerable item.

SCREW PROPELLER.

The screw propeller is vastly more complex in its action than either of the simple propellers we have been considering, for three reasons:—(1) the action is oblique instead of direct; (2) the velocity of each particle of water acted on by the propeller is not the same; (3) the screw always operates on water which has been previously disturbed by the passage of the ship, and the difficulties thus created are so serious that at present the problem cannot be said to have received complete solution. It would be impossible for us to enter on this question at the end of an article already too long; we shall therefore confine ourselves to a remark on oblique action which immediately follows from what has been said.

Oblique action is always, other things being equal, a cause of inefficiency in a propeller, as has been suffiiciently explained above, and it may be asked how this is consistent with the fact that the screw propeller is a practically efficient propeller. The principal and probably the only answer to this question is, that a screw of large size operates on a vastly greater body of water than any paddle-floats which could be put into the same vessel, and it has been shown above, that, other things being equal, the efficiency of a propeller is greater the more water passes through it. Yet no doubt it is conceivable that in some cases there might be less "churning" in an oblique acting propeller so as partially to balance the loss by lateral motions.

In conclusion, we must say that it is hardly possible to do justice to the subject within the limits of a few pages; we shall be content if we have succeeded in showing that the modern theory of propulsion is something more than a mere hypothesis, resting, as it does, on the secure basis of an old and well-known mechanical principle, interpreted and applied in a manner suitable to the problem under consideration.

THE THEORY OF THE HOT BLAST.

(*Continued from page* 552.)

Suppose now in this Guerche furnace, containing, probably, only 3,000 to 4,000 cubic ft., it were attempted to smelt Cleveland ore, which, so far as yield of iron and consumption of flux are concerned, nearly approaches that affording the results just given.

In order to prolong the contact between the ore of Yorkshire and the reducing gases, as well as to increase the deoxidizing power of the latter, probably not far short of 65 cwt. of fuel would be necessary to obtain a ton of iron. No less than 40 cwt. being thus expended in establishing the proper relations between the co-efficient of fusion and that of reduction.

There is, however, another method in making amends for this want of harmony between the two functions of the blast furnace. Instead of delaying the fusion of solids, and increasing the energy of the reducing gases by the addition of CO, the same object may be attained if contact is prolonged in a furnace of larger capacity.

In illustration of this mode of action, I will again quote from the experience and figures kindly communicated to me by my friend, Mr. Horton, of the Lilleshall Iron Company.

In furnaces having a height of 53 ft., driven with cold air, an ore poorer than the Scotch black band, and containing about 43 per cent. of iron, calcined, was smelted with about 40 cwt. of coke, affording another case of an ironstone more reducible than those which hitherto have formed the favorite basis of estimating the effects of the hot blast.

Here the available heat may be taken at fully 25,000 cwt. units beyond that which could possibly be absorbed in the process, and which, in consequence, must have escaped from the throat.

Mr. Horton, encouraged by the example of the Cleveland ironmasters, proceeded to add to the capacity of his furnaces. Having to deal with materials entirely different in character from those used in the neighborhood of Middlesbrough, this gentleman deemed it prudent to proceed with caution, and therefore contented himself with raising his furnaces to a height of 71 ft.

The result was most satisfactory, and at Lilleshall may be seen six cold blast furnaces, making good foundry iron with 27 or 28 cwt. of coke, which is fully as small a quantity as would have been required in the old furnaces of 53 ft. had they been blown with an air at 450 deg.C. (842 deg. F.)

Possibly, looking at the tender nature of the coke at Lilleshall, and the size of the ironstone, Mr. Horton may have been quite right in not venturing on the adoption of the dimensions found now so commonly on the banks of the Tees, where the coke is dense and the ore in large pieces. Were it possible, however, to treat the Shropshire minerals in furnace 80 or 85 ft. high, so far as fusion and reduction are concerned, I apprehend there is little doubt the coke consumption might be reduced to that of Guerche, viz., 25,000 cwt. to the ton of iron, for it is obvious with an escape of 25,000 cwt. units there is still a considerable margin for economizing.

Had such an alteration, as that just described as having been made at Lilleshall, been carried into effect before the introduction of the hot blast, even in the then state of knowledge of the theory of iron smelting, the inference would have been inevitable, that the advantage obtained by raising the furnace was solely due to its imperfect nature—in short, that just as the Stückofen was inferior to the first high blast furnace, so was the furnace of 53 ft. at Lilleshall inferior to that of 71 ft.

Like the discovery of Abraham Darby in using mineral fuel for iron smelting, it is impossible to overrate the value of the hot blast at the period of its first introduction. Indeed, I am not prepared to say that for the black band of Scotland, it may not have nearly as great a value still, due to some mechanical difficulties in its treatment, such as forcing the blast through a very high column composed of this mineral and raw coal, and which, therefore, may render a lower furnace necessary, unless when assisted by Mr. Ferrie's coking chambers. In this opinion I am guided by the alleged want of success experienced by the Scotch ironmasters, when they raised their furnaces in former years, and by the opposite results obtained by Mr. Ferrie.

Apart from any such impediments as those just mentioned, what I consider as beyond all doubt is, that the value of the hot blast at the period of its invention was, so far as any "extraordinary effect" is concerned, solely due to the defective nature of the furnaces then in use, and that when this is remedied, 1,000 units of heat in the blast can be as easily accounted for as a similar quantity derived from the combustion of fuel in the hearth.

We have only to appeal to the knowledge afforded at Lilleshall in verification of this statement. Foundry iron is there produced with cold air by, say, $27\frac{1}{2}$ cwt. of coke. Let 12,000 heat units be thrown in with the blast, which are equivalent to 4 cwt. of coke burnt with air at 485 deg. C. to CO. This at once is a reduction of the fuel consumed to $23\frac{1}{2}$ cwt., which is probably not far off the actual quantity furnace of 71 ft. would require.

Speaking from the accumulated knowledge respecting the action of iron smelting obtained in recent years, we have seen that valuable as the hot blast was when applied to furnaces of moderate height, it was far from remedying entirely the structural defect alluded to above, for it was not until those of the largest description had their capacity doubled, that something like the full economy in smelting the ore of Cleveland was reached.

Returning for a moment to the enlarged Lilleshall furnaces, we have seen that precisely the same object was secured, whether, as in their case, an addition to the size was the means employed, or the blast was heated. Exactly the same law holds good with the furnaces of the former moderate dimensions heated with air at 450 deg. C. They may be enlarged, as has been done in most cases in the North of England, or they may be retained of lesser dimensions, and fed with air at 600 deg. to 700 deg., according to the mode pursued at Consett.

The limit, or what I have already stated, and what, in a future section, I shall again state, I consider to be—the limit of economy, once reached, very large capacity and very highly heated blast simply tend to neutralize each other.

It may be urged that whether a certain number of heat units is communicated to the blast, and, rising upwards, is intercepted and returned downwards, or whether the same result is brought about by an increase of capacity in the furnace, the effect upon the temperature of the crucible will be the same, and that in each case, it may be supposed, the heat of the latter will be augmented.

Not having access to any furnace (close topped) using cold blast as would permit an accurate examination of the actual temperature of the escaping gases, after an addition to its capacity has been made, I have been unable to prove, by actual experiment, what the effect has been of such increase of size, and of comparing such results with those at furnaces of similar dimensions using hot air, both being engaged in smelting the same kind of ironstone. Under these circumstances, I have been compelled to make use of such data as I possess, which, unfortunately, are not the best fitted for the object in question, because the materials under treatment differed considerably in their nature.

The furnaces selected for the purpose were two at Cyfarthfa, 52 ft. high, one blown with cold air, and the other with its blast at 332 deg. C. (610 deg. F.) The latter, using fully 8 cwt. less fuel per ton of iron than the other, nevertheless, had its gases passing off 60 deg. C. (108 deg. F.) hotter than those of the cold blown furnace.

It was mentioned, in the present section, that waste of fuel in the blast furnace arose from a want of harmony between the operations of fusion and reduction, the latter not keeping pace with the former. I have shown how this was remedied by increasing the opportunity the reducing gases had for acting on the oxide of iron. This was effected by a prolongation of contact, obtained by enlarging the furnaces; but we have only to refer to those experiments which were undertaken for the purpose of ascertaining the laws which regulate the conduct of the substances met with in the process of smelting an ore of iron, to see that the shorter period of contact can be maintained, or even curtailed, provided the energy of the reducing agent is augmented. Thus in Exp. 36, while calcined Cleveland stone lost 37.3 per cent. of its oxygen in 8 hours, by being exposed to CO at a temperature of 410 deg. C. (770 deg. F), the same ore lost (Exp. 49) 63 per cent. at a dull red heat in the same time, and 90 per cent. (Exp. 50) was expelled in $3\frac{3}{4}$ hours, the temperature being that of bright redness.

I infer, therefore, that the improvement by the use of the hot blast, is not due to any additional heat reconveyed to the hearth, but that such heat is utilized in promoting the energy of the reducing gases in the upper zone, and having done this, it is carried off from the outlet of the furnace. The reasons have been mentioned to show it is unlikely that the temperature of the hearth is really sensibly increased, and also that a very small addition to that of the escaping gases greatly augments the power they possess of causing reduction. It seems to me, therefore, much more probable that the advantage derived from the use of heated air must be ascribed to the increased temperature in the upper region of the furnace by which the process of reduction is hastened in a corresponding ratio. In this way, although fusion goes on at an increased speed in the hearth of hot-blast furnaces, on account of the decreased quantity of fuel by which it is effected, as reduction experiences a still greater acceleration, the two operations are carried on in harmony, in point of time, with each other.

If, then, we take the case of a cold blast furnace of 52 ft., consuming any given quantity of coke per ton of its product, I say that the temperature of the hearth is the same as that of any hot blast furnace producing the same quality of metal, from the same materials, and that the action of reduction being too languid in comparison with the process of fusion, a loss of fuel is the result, in the manner already described, and that this loss may be remedied either by prolonging contact, or by increasing the energy of the reducing gases by communicating heat to the air used for effecting the combustion of the carbon in the hearth. Further I say that when no such want of harmony between the two branches of the process obtains, as in the case of the furnace at Guerche, no such stimulus as that afforded by the hot blast is required. From this latter statement it must not be concluded that no saving in fuel would accrue to a furnace using 25 cwt. of coke to the ton of iron by the addition of a high temperature to the blast. The calories, however, so contributed, would be found to correspond, in all probability, very closely with those afforded by so much coke economized by the change.

I may be excused, if I parenthetically notice the great advantage to be derived from a perfect understanding of the fundamental principles which lie beneath a process so essentially chemical as that carried on in an iron furnace. It seems scarcely possible to imagine that had the ironmaster, before Neilson's time, been aware, and, being aware, had seriously considered, that in many cases, out of 133,000 calories actually evolved, he only beneficially applied 49,000, or about ⅓ of the whole, we should not have had to wait for the accidental observation of a thoughtful gas-works manager, before attempting to avoid part of the loss of 63 per cent. of his fuel, which might have been done by the simpler plan of increasing the size of the furnace, in which, if the remedy be not perfect, it is at least as much so as that effected by the hot blast itself.

Greatly curtailed in point of importance, as I deem the use of hot air to be, since the adoption of recent improvements, I would not have it supposed that it has to be regarded in any other light than that of a very powerful and valuable aid to the iron smelter. Its mode of application is so direct and simple that heat may be conveyed in greater or less quantity, as may be required, at once to the focus of most intense temperature, without waiting for a change in the materials, which requires some time before it reaches the tuyeres. This assistance, too, is afforded by a fuel, the escaping gases of which, in many cases, if not so applied, would be wasted. These attributes, even in their modified form of usefulness, will, in my opinion, insure for Neilson's discovery a lasting position in the science of iron metallurgy, and will preserve for his name an exalted place among the most illustrious of those who, by their ingenuity, have advanced the industrial resources, and, therefore, the national importance of their country.

ON THE EFFECT OF THE HOT BLAST ON THE QUALITY OF THE IRON.

Like many new inventions, the hot blast met with considerable opposition at the period of its introduction. In Scotland, including the coal used at the blowing engine, the waste incurred in coking the coal, and all other items, the reduction in the quantity of fuel often amounted to 75 per cent. According to M. Dufrenoy, the money value arising fron this source, and that derived from a diminution in the general working charges, from the increased make, amounted to £1 5s. 11d. per ton of iron, made with air heated to 322 deg. C. (611 deg. F.)

With the Scotch pig iron makers, this difference in cost bore down all resistance, and every establishment in that part of the kingdom was speedily blown with hot blast. Wales up to the period of Neilson's discovery, was, according to Dufrenoy, able to produce pig iron at a lower rate than any other locality in Great Britain. Unfortunately for the Principality, the mere act of heating the air completely changed the aspect of affairs, for while this modification of the manufacture was followed by a saving of 26s. per ton in Scotland, something like 1s. 8d. was all the benefit its adoption was, according to the French engineer, able to afford to the Welsh ironmaster.

The Glasgow makers enjoyed immense advantages in the possession of their cheap and rich ironstone, but unfortunately, these were in a great measure, neutralized by its refractory nature when smelted in small furnaces (50 ft.) with cold air, a difficulty which involved the consumption of a large quantity of fuel, raised at a higher price than that of the Welsh coalfield. This objection was remedied by the addition of 600 deg F. to the blast.

In Wales, on the other hand, the ironstone was poor, but easily smelted; the coal was cheap (3s. 7d. per ton, Dufrenoy states), rich in carbon so that 50 to 54 cwt. were able to produce a ton of metal. This quantity could only, it was estimated, be reduced 17 cwt. by the use of the hot blast, from which had to be deducted 6 cwt. consumed in the heating apparatus, leaving a net gain of 11 cwt., equal to the saving of 1s. 8d. per ton, of which 1s. had to fall to the share of the patentee.

After some unsuccessful litigation in disputing the legal position of Mr. Neilson, many of the Welsh ironmasters discontinued the practice of heating the blast, it being pretended that the trifling saving in cost was more than swallowed up by the inferior quality of the iron made by its means.

However sincere these manufacturers may have been at the time in question, further experience has modified their ideas, for at the present day by far the larger number of furnaces in Wales is blown with hot air.

It is now upwards of forty years since Neilson patented his discovery, and it is not a little remarkable that this question of quality cannot be considered as entirely settled yet. If the matter had to be judged by the acts of the majority of the manufacturers, then undoubtedly it might be inferred that the present cases, so few are they, where cold blast is still adhered to, might be regarded as the last signs of life in a struggle against speedy extinction. Large, however as this preponderance of opinion may be in favor of hot air, it has the objection, it may be urged, of being entertained by those who may be supposed to prefer its use on account of the cheapness it has been the means of introducing into their process, and the great command it gives over the operation.

With every wish to deal fairly with the disputed point of quality, its decision is surrounded with much difficulty, and is one which requires great experience, before any individual is justified in speaking with the necessary confidence even on facts capable of more speedy demonstration than those appertaining more immediately to the use and durability of the product. In illustration of this, I may observe on referring to some early notebooks of visits to the Welsh works, that the opinion was then pretty generally entertained that the whole of the advantages obtained in the blast furnace by the use of hot air was, by the waste of iron and defective quality, lost in the forge and mill.

The present generation, however, as a rule, has turned its back on the creed of its predecessor, and the advantages of hot blast, at all events as a matter of economy, are, in our time, universaly admitted. As regards the alleged loss in the process of converting the pig into malleable iron, I have the indisputable authority of my friend, Mr. Menelaus, of the Dowlais Works, for stating that this is a mere illusion, and that small, comparatively speaking, as the saving of fuel in the blast furnace is in Wales (about 15 cwt.), the advantages of hot air cannot be denied by any one who has paid proper attention to the subject. This it must be recollected, is, of course, not a carelessly adopted view, but one which is the result of comparing whole years' operations conducted under the two systems.

During the recent visit of the Iron and Steel Institute to Staffordshire, I made the subject a matter of constant inquiry. I cannot say the answers received were universally in one direction, but there is no manner of doubt the large preponderance of opinion, and this from makers of immense experience, is, that from the same materials there is no appreciable difference between hot and cold blast pig, nor in the malleable iron afforded by the two kinds of metal.

My experience in foreign countries leads me to believe that this is the view entertained by the great majority of those producers of the fine descriptions of charcoal iron, whose position in the market is entirely dependent upon the world-wide reputation of their limited make. With few exceptions, I found these Continental manufacturers had applied hot air to their furnaces; as, for example, in Norway and Sweden, when treating the pure magnetic oxides of these countries, in Styria and Carinthia, for smelting the fine spathose ore of Eisenerz and Lölling, and at Fullonica, when using the specular ore from the neighboring island of Elba.

At Dannemora, it is true, they adhere to cold air, on the ground, as I was informed that the quality of their well-known brand had suffered by an attempt to use hot air.

Professor Tunner * on the other hand, who has had large experience with the manufacture of the pure charcoal iron at Eisenerz, asserts positively that deterioration is no necessary consequence of the use of hot blast.

When such very minute quantities of certain substances, such as P, S, Si, etc., are known to be capable of affecting in an unmistakable manner the properties of iron in which they occur, it is, perhaps, an act of over-refinement to reason upon their being present in greater or less amount, from our presumed acquaintance with the

* Russland's Montan Industrie insbesondere dessen Eisenwesen. Leipsig, 1871.

nature of the smelting process, when carried on by means of air heated or otherwise.

It may be urged, and perhaps reasonably so, that our knowledge of this subject is too limited to deal satisfactorily with so delicate a matter as that in question; at the same time we must make the best use we can of the information we possess, and the argument based thereon must be judged accordingly.

Viewing the action of the blast furnace comprehensively, I have regarded the actual work done as performed identically in the same manner, whether the air is used hot or cold. Thus, in the Lilleshall 71 ft. furnaces, we have the combustion of about 28 cwt. of coke, affording the necessary heat for smelting iron from an ironstone yielding 40 to 43 per cent., by giving the gases time enough to become saturated with O, and so to communicate their sensible heat to the descending materials, that when the latter reached the tuyeres the store of heat they contained, added to that evolved by the combustion of the fuel, sufficed for the required duty, without any heat being communicated to the blast. If the furnace, instead of having a height of 71 ft., had only 48, the work was inefficiently performed, and had either to be supplemented by the hot blast or by the consumption of a larger quantity of fuel in the manner already explained. By an increase of capacity and the use of hot air, a further economy of fuel may be effected, and this continues until the gases are fully saturated with oxygen.

In effect, then, as has been already stated, for a similar quality of iron, an identity of temperature ought to be found in every furnace, whether the air which enters it is hot or cold. If this be so, then in the matter of temperature there is no reason why iron made in either way should differ materially.

If, on the other hand, as has been and is often alleged, the effect of heated air is to deteriorate the quality of the pig iron, we might reasonably expect that this deterioration would keep some kind of pace with the elevation of temperature conferred on the blast.

In comparing hot with cold blast iron, I speak with hesitation, from my want of experience with the latter, but in dealing with iron made in furnaces blown with air at about 350 deg. C. (662 deg. F.) up to 500 deg. C. (932 deg. F.), I labor under no such disadvantage. I may, therefore, confidently state from my own personal acquaintance with both, that the quality of the product has in no way suffered by the change from the lower to the higher of these temperatures of blast. Indeed, I may go further, and give it as my own opinion that there has been an actual improvement, which I attribute to the use of a less quantity of fuel, for, if reference is made to Section 35, on the behavior of P and S in the blast furnace, it will be seen there is an appreciable quantity of both these elements in the coke. Anything, therefore, which lessens the extent to which these acknowledged hurtful ingredients enter the furnace, must be beneficial, and one cannot be surprised that the iron has not suffered by raising the temperature of the blast, accompanied, as this has been, by a diminution in the quantity of fuel.

Looking back at the figures contained in the section mentioned above, it will be seen that the phosphorus entering the furnace, when using hot air, for each 100 parts of iron produced, amounted to 1.578, and the sulphur to 4.456. Were this furnace using 3 tons of coke per ton of iron, the phosphorus would be raised to 2.055, and the sulphur to 7.3 parts per 100 of pig.

These arguments, based on the action of the blast furnace, so far as they go, would point to the conclusion that hot blast, far from acting hurtfully on the iron smelted by its aid, will produce a marked improvement by the change in its temperature. At the same time, however, we must not overlook the fact that in the hearth of the blast furnace there is constantly occurring a series of very complicated, and, perhaps, not very well understood, chemical changes, which have been touched upon when speaking in Sections 26 and 34, on the generation and decomposition of certain cyanogen salts. Whether or not slight changes in local temperature may affect the order of chemical action, which appears very active near the tuyeres, it is impossible, in our present state of knowledge, to say.

The experience in the manufacture of Bessemer steel affords some information to guide us in the consideration of this intricate problem now under consideration. If a sample of pig is delivered to the bar iron maker, containing a large percentage of phosphorus, the action of the puddling furnace removes by far the greater proportion of this substance.

Exp. 752. A specimen of pig iron was ascertained to have associated with it

P 1.33 per cent.
S .158 "

the puddled iron made from it contained, of P, .29 per cent.; and of S, a mere trace.

Exp. 753. A second sample of pig iron, containing about $1\frac{1}{2}$ per cent. of P, yielded a puddled bar, giving only .33 per cent. of this substance.

In the Bessemer converter, no such removal of phosphorus takes place, and as its presence in quantity amounting to less than one-tenth per cent. is fatal, the steelmaker has no alternative but to employ pig iron almost entirely free from this element. Sulphur, too, is equally shunned by the producer of Bessemer steel. Now if the action of hot air, in the blast furnace, tended in any way to concentrate the quantity of either phosphorus or sulphur in pig iron, it is clear its use would be more carefully avoided in the manufacture of that intended for the steel works than that destined for the manufacture of bar iron, inasmuch as the puddling process is capable of removing partially, at all events, the phosphorus, which is not the case with the Bessemer converter. This view of the question, of course, confines the cause of deterioration to sulphur and phosphorus. It is possible that some other ingredients may, by their presence, prejudicially affect the quality of iron, such, for example as silicon, but I am not aware that those who advocate the use of cold blast have ever succeeded in demonstrating that the superiority of iron, so smelted, was indebted for its alleged higher excellence to the absence of any particular ingredient or ingredients found in metal produced with hot air.

At the present time, when the relative merits of the two systems of manufacture are compared, reference is very generally made to the high character of certain well-known brands of iron, which being produced exclusively by means of cold blast, are regarded as affording incontrovertible proof of the superiority possessed by the ancient mode of smelting.

It is almost superfluous to say that it is in the highest degree unphilosophical to institute any comparison between hot and cold blast iron, unless in each case the minerals are precisely the same. To some extent this has been done, and it would appear that, according to the experiments of Fairbairn and Hodgkinson, already referred to, when the hot blast was applied to the minerals used at the Devon and other iron-works, there was an evident improvement in the strength of the pig iron.

At that period too little importance was attached to the chemical constitution of pig iron to have prompted any one to ascertain, by actual examination, whether any change in this respect had been induced by heating the air, and at the present day it is, so far as my inquiries go, impossible to obtain specimens of hot and cold blast iron smelted from exactly the same materials.

The nearest approach I have been able to make to this is afforded by the assistance of my friend, Mr. Walter Williams, the well-known Staffordshire ironmaster, and even here, the specimens are far from being all that is to be desired.

The cold blast iron was the produce of the Staffordshire clay ironstone, smelted with South Staffordshire coke, and with the Dudley limestone as a flux. The hot blast iron was obtained from the same Staffordshire claystone, mixed with one-sixth North Staffordshire black band, and one-sixth red hæmatite. The limestone employed in this case was from Wales, but the fuel used was the same as in the cold blast furnace. There were thus two important deviations from identity in the materials—the ore in the hot blast furnace contained one-third of hæmatite and black band, which were not present in that blown with cold air, and the limestone was different.

So far, however, as phosphorus is concerned, as the red ore is free from this ingredient, the sixth part of black band is the only source likely to bring any addition to this element, unless the flux from Wales is richer in P than that from Dudley.

Neither of these possible causes of contamination, however, have added, practically, either to the amount of phosphorus or sulphur contained in the hot blast iron, as may be seen from the following analyses, carefully done by my present assistant, Dr. Watson. Both samples were No. 3 in quality.

	Exp. 754. Cold blast.		Exp. 755. Hot blast.	
Fe	93.761		92.201	
C. graphite	3 062	3.405	2.568	3.161
combined	.343		.593	
Si	1.025		2.080	
S	.077		.065	
P	.663		.686	
Mn	.819		1.549	
	99.750		99.742	

In these experiments, there is a considerably larger quantity of Si in the iron produced by the hot, than by the cold blast furnace. In examining some of the analyses quoted in "Watt's Dictionary of Chemistry," the Si, in some cold blast iron, exceeds even the quantity given above; thus, in specimens of Dean Forest iron, made with cold air, 2.34 and 2.10 per cent. are given as the content of Si. Knowing from my own experience, however, how irregular the quantity of Si is in metal made in our own furnaces, blown with heated air, I was not disposed to attach much importance to this; nevertheless, other pigs of the same Staffordshire iron were sampled, and these, on trial, gave results which confirmed my opinion on the uncertainty as to the existence of Si in definite quantities.

	Cold blast.
Exp. 756. No. 2 iron, Si %	1.446
" 757. " "	1.294
	Hot blast.
Exp. 758. No. 2 iron Si %	2.521
" 759. " "	1.948

The only other notable difference between the two kinds of iron was the larger proportion of manganese in that made by hot blast. The presence of this substance was more likely to be an advantage than otherwise, but, to see whether its larger presence was accidental or not, further trials were made:—

	Cold blast.
Exp. 760. No. 2 iron, Mn %	1.060
" 761. " 4 " "	.953
	Hot blast.
Exp. 762. No. 2 iron, Mn %	1.726
" 763. " 4 " "	1.253

These numbers indicate that the metal, in question, occurs in larger quantity in hot blast iron, made of the minerals already specified, than is found in cold blast iron, from a mixture of ore of a somewhat different character.

I have in vain sought to connect the alleged superiority in quality, said to be enjoyed by iron manufactured with cold air, with any freedom from those substances generally considered as affecting prejudicially the character of pig iron. Of course, in them, as in all iron, hot as well as cold blast, we are pretty safe in asserting that excessive quantities of Si, P, or S, are hurtful, but on referring to a list of analyses in Bauerman's work on the "Metallurgy of Iron," it will be found that certain highly esteemed brands of cold blast iron appear to contain more of these substances than do others much less favorably known in the market.

Upon one occasion, the subject was made one of direct experiment at the Clarence Works. A furnace, about to be extinguished, was blown with cold air for a short time, the burden of ironstone, of course, being reduced to meet the change of circumstances. The trial was made some years ago, and the pig iron not having been submitted to analysis, I cannot speak as to its composition; but so far as the quality of bar iron it afforded is concerned, I know positively there was not the slightest trace of improvement.

It is almost needless to observe, that a belief in the absence of any advantage in the quality of iron produced by one mode of manufacture or another, does not involve any doubt as to the excellence of the produce of certain works which happen to be made by means of either; all that is intended to be conveyed by the general tenor of the present remarks is, that it scarcely has been satisfactorily proved that the excellence in question is really due to the temperature of the blast used in the smelting process. I have been given to understand that, in some establishments, making high-class iron, when a furnace, worked with cold blast, is driven so as to produce above 90 tons a week, an unmistakable deterioration in the quality of the bars obtained from pig iron manifests itself. Acceleration alone, in the speed of driving, may of itself give rise to an increase in the intensity of temperature evolved from a given quantity of carbon; but, at the same time, it is much more likely that the depreciation in quality, if it occurs, is due to a reduction in the actual heat of the hearth, which will be caused by a portion of the reduction being effected so low down in the furnace that the CO_2 dissolving C diminishes the weight of coke for combustion at the tuyeres, which, of course, will be followed by a lowering of temperature.

It might be inferred that when the

problem to be solved was the mere determination of certain physical properties, there ought to be no difficulty in ascertaining the relative power of resistance possessed in every conceivable direction by iron, cast as well as wrought.

All this has been done, and well done, at a very early period by Fairbairn and Hodgkinson, at the request of the British Association for the Advancement of Science. According to the report of these gentlemen, results were obtained of a somewhat unexpected nature ; at all events, they certainly do not coincide with the relative estimation in which certain brands of iron were held, and continue to be held, in the market. The following figures are taken from one of their tables :

	Tensile strength per square inch of section in tons.	Crushing strength per square inch of section in tons.
Low Moor No. 1, cold blast	5.667	27.003
" No. 2, "	6.901	42.324
Bowling No. 2, "	6.032	33.507
Clyde iron No. 1, hot blast.....	7.198	40.535
" No. 2 "	7.949	47.326
" No. 3 "	10.477	47.338

The following table contains the data of different makes of pig iron manufactured by hot and cold blast, as determined by the same authorities as the preceding, in which the ratio between the two is given, cold blast being represented by 1,000. From these it would appear some irons are improved, and others are deteriorated in quality.

	Carron, No. 2.	Devon, No. 2.	Buffery. No. 1.	Coed-Talon No.2.	Carron, No. 3.
Tensile strength............................	809	....	769	884	1,250
Compressive do..	1,020	....	925	1,012	1,156
Transverse do..	991	1,417	931	....	....
Power to resist impact....	1,005	2,786	963	....	....
Transverse strength of inch square bars...............	973	1,199	942	....	....
Ultimate deflection do. in inches	1,018	1,380	1,058	....	....
Modulus of elasticity per square inch.....................	931	991	893	....	....
Specific gravity..	997	991	989	1,002	989

More recently, Mr. Kirkaldy has bestowed much attention on the strength of iron and steel, and the results of his investigations have been published.* From these the following numbers have been extracted to show that the more expensive irons do not exhibit a corresponding power of resistance. The specimens, Mr. Kirkaldy states, were obtained promiscuously from merchants' and engineers' stores, and in each case a rolled bar, 1 in. in diameter, was taken :—

BRAND.	Number of expts. of each.	Breaking weight per sq. in. of original area.		
		Lowest.	Highest.	Mean.
		Lbs.	Lbs.	Lbs.
Low Moor....................................	4	59,320	65,166	61,798
Bowling....................................	4	58,678	65,701	62,404
Bradley..	4	56,004	58,036	57,216
Govan (Scotch)....................................	4	57,738	59,726	58,746
Govan (Scotch) B. Best...........	4	60,069	66,363	62,849

Later still, M. Knut Styffe, the Director of the Royal Technological Institute of Stockholm, by order of the Government, undertook a series of investigations, which are recorded in a book on the "Elasticity, Extensibility, and Tensile Strength of Iron and Steel."† In this book, information of temperature at which fracture took place, and the carbon and phosphorus in the bars are given :

*"Experiments on Wrought Iron and Steel," 1863.
†Translation by C. P. Sandberg. By Murray, London, 1859.

BRAND.	Per cent. Carbon.	Per cent. Phosphorus.	Diameter of round bar	Temperature of bar, F.	Breaking weight per sq. in of original area.
			In.		Tons.
Low Moor (cold blast)	.21	.068	.465	− 32	27.35
" " "	"	"	"	+ 68	25.21
" " "	"	"	"	+ 59	29.10
" " "	"	"	"	+ 323	29.62
Middlesbro' (hot blast)	.07	.250	.581	− 40	27.44
" " "	....	....	....	+ 57	25.81
" " "	....	....	....	+ 60	23.58
" " "	....	....	....	+ 59	26.46
" " "	....	....	....	+ 318	31.12

The pages from which the preceding figures are extracted contain much information which would be out of place in such a work as the present.

My object has not been to compare the relative value of different kinds of iron, but to show how difficult it appears to be to prove the resisting power of either cast or wrought iron by mere experiment.

It must be remembered that the researches which gave the results just quoted, by no means represent the conditions of actual use. A cube or cylinder of cast iron may have a high tensile or compressive strength, but from excessive contraction in cooling in a large casting, may be in such an unequal state of tension as to break on concussion. In like manner, bar iron may, from causes our present state of knowledge does not enable us to explain, have great tensile strength, and yet be less able than others to resist those violent shocks to which in many cases it is exposed.

All this goes to prove that it is long experience alone which secures, and properly secures, for any particular mark that preference which commands a high price in the market, and this position it necessarily maintains against the produce of any less well-known manufacturer, who, nevertheless, may possibly turn out an article in all respects equal to that of his better-known rival.

My intention in this section, however, is not with this aspect of the question. It is simply to express the opinion that no satisfactory proofs have been published to show that the use of hot blast is attended with hurtful effects on iron produced by its means, while many manufacturers, well known for the quality of their make when cold blast alone was employed, have commenced the use of hot air without injury to the character of their iron; and further, that we have the evidence of authorities like Professor Turner in favor of the view, that whether iron is smelted by heat intercepted in the upper part of the furnace, or by fresh heat added to the blast, the resulting temperature in the hearth, I maintain, being, in all probability, the same in each case, is immaterial so far as the nature of the product is concerned.

A NAVIGABLE BALLOON.

From "Engineering."

The trial of M. Dupuy de Lôme's balloon, has certainly taken the importance of a scientific event in Paris. The construction of this aërial machine, starts with the principle, that to obtain a navigable balloon, the two following conditions must be complied with:

1st. The permanence of the form of the balloon, without any sensible undulation of its surface.

2d. Obtaining a horizontal axis of least resistance in a direction parallel to the propelling force.

The permanence of force is assured by a fan carried in the car, and put in communication by a tube with a small balloon placed within the large one at its lowest part. The volume of this small balloon is one-tenth of that of the large one. It is furnished with a valve opening both within and without, and regulated by springs. The large balloon is provided with two hanging tubes open to the air, and falling for a distance of 25 ft. from the lower part of the balloon. The inflation of the little balloon causes the hydrogen to fall more or less in the hanging tubes, but never sufficiently to force it out of their open ends.

To obtain a horizontal plane of least resistance, the form given to the balloon was that developed by the arc of a circle turning around its chord, and in which the versed sine was nearly one-fifth of the length of the chord.

The following are the principal dimensions of the balloon:

	ft.	in.
Total length from out to out	118	6
Greatest diameter	48	9
Cubic contents	122,000	0
Total height from top of balloon to bottom of the car	95	6
Length of the car	41	3
Greatest width of the car	10	8
Diameter of screw	29	6
Pitch of screw	26	2

Ascensional force:	Tons.
With small balloon, not inflated	3.799
" " inflated	3.419
Number of revolutions of screw per minute to obtain a speed of 5 miles an hour	21
Time required to fill the small balloon by aid of the fan	15 minutes.

The upper portion of the balloon is covered with an envelope of fabric, which supports the car by a zone placed around the centre of the body. This envelope is then continued below the upper half until it covers about three-fourths of the body. Below the envelope, and attached in a similar manner, is a second zone within the first one, having the form of a cone tangential to the sides of the balloon. The summit of this cone serves to attach the cordage by which the car is sustained.

The rudder consists of a triangular sail placed beneath the balloon and near the rear, and it is kept in position at the bottom by a horizontal yard 19 ft. 8 in. long, turning around a pivot on its forward extremity. The height of this sail is 16 ft. 4 in., and its surface 161 sq. ft. Two ropes for working the rudder extend forward to the seat of the steerer, who has before him a compass fixed to the car, the central part of which is large enough to carry a crew of 14 men. The forward and aft parts are formed with a framing of bamboo.

The screw is carried by the car. The shaft can be easily lifted from the rear, and thrown upon a forward support, so that no damage can arise to it, either on departure or arrival. The screw is driven by four men, or by eight men working at a capstan. The gas-escape valves, of which there are two, are placed at the top of the balloon, immediately over the pendent tubes, before spoken of, and through which the cords for working the valves pass into the car. The balloon is made of white silk, weighing about 7 oz. per sq. yard, with 7 thicknesses of caoutchouc superimposed; the envelope also is of white silk. The joints are so arranged that they are stronger than the material itself. On the inner face, three coats of varnish were applied, formed of gelatine, glycerine, pyroligneous acid, and of tannin. Such a varnish is impermeable to hydrogen.

The balloon, properly called, weighs about half a ton, and the total weight of the whole machine is 1.753 tons. The crew, luggage, provisions, instruments, etc., weigh 1.446 tons. Of ballast $\frac{2}{3}$ds of a ton are taken. Collectively, these figures give 3.85 tons, equal to the full ascensional power at the ground level.

M. Dupuy de Lôme had calculated that, with a speed of 5 miles an hour, the resistance of the balloon in the direction of its main axis, would be 24.26 lbs., and that the speed of the screw should be 21 revolutions per min. to overcome this resistance. This speed could be easily obtained by four men working for half an hour, and being relieved at the end of that time by four others; with the eight men working together at a capstan 27 or 28 revolutions could be obtained, which would give a speed of about 8 miles an hour.

The stability assured by the system of suspension adopted, is such that even under the maximum effort of eight men working the screw, the equilibrium was only disturbed half a degree, and a man in walking from one end of the car to the other only affected it by half a degree.

The apparatus for producing the hydrogen by the action of diluted sulphuric acid and iron turnings, consists of two batteries of 40 casks, each producing at one operation lasting 3 hours, 5,375 cubic ft. of hydrogen, and working alternately.

At the trial trip three days were required to fill the balloon. It was ready on the 1st of February, in the evening, and it was kept inflated all night, but at two in the morning it was allowed to ascend sufficiently to attach the car, rudder, fan, connections, etc. The loss of gas during the night had been inappreciable, and previous experiments showed that the varnished silk was perfectly reliable. The wind had risen and the meteorological bulletins were far from being encouraging. However, the inventor decided to make the ascent, and after having repaired a slight damage, he left the ground at 1 P. M.

There were about two-thirds of a ton of ballast on board, and the balloon was in perfect equilibrium; 350 lbs. of ballast were thrown out, and the ascending force thus produced carried the balloon up rapidly.

A strong wind was blowing from the south. A few minutes after the departure, the shaft of the screw was lowered upon its bearing, and was started by the eight men together, slowly at first, and then with an increased speed. The rudder was first moved to the right, then to the left, and then was adjusted in order to ascertain how far its influence would be felt by the balloon. When the screw was set in motion, the effect of the rudder was immediately felt, as desired, proving that the balloon had acquired a sufficient speed with relation to the surrounding air.

The experimental trips had a threefold purpose: to ascertain the stability of the balloon, the relative speed that could be obtained, and the manner in which it obeyed the rudder, either on a fixed course or in tacking. An anemometer previously regulated gave the relative speed of the balloon; a compass attached to the car indicated the direction of movement. To measure the course followed in relation to the ground, a planchette was fixed to the side of the compass parallel to the vertical plane, and in the direction of the true north. The field of the planchette was painted black, the part forming a vertical surface being white. By this arrangement it was very easy to obtain a visual ray in a vertical plane, the verticality of the planchette being assured by the mode in which the compass was hung. By observing any clearly defined object on the ground, passing beneath the observer, and then by turning the planchette in the direction of the same object, when it was shifted from the vertical plane, the direction of the route followed by the balloon could be read direct off the compass.

The same observation gives the speed of the balloon, the height being observed by a barometer.

Between 1.15 P. M. and 2.35 P. M. eight observations were taken of the height of the balloon, of the temperature of the route measured on the ground in relation to the magnetic meridian, four times with the screw not working, and four times whilst it was being driven by eight men. At 2.35 P. M. it was resolved to descend, and at 3 P. M. the balloon touched ground at Mondécourt, exactly at the village indicated on the map of the route laid out beforehand from the calculated deductions of direction and of speed.

The landing was effected with perfect success and without accident, in spite of the force of the wind. M. Dupuy de Lome arrives at the following conclusions from the results of the trial: That the stability of the balloon was perfect, that it manifested no signs of oscillation under the action of the eight men working the screw, and that the shifting of the weight in the car produced no sensible movement. The vertical axis was only shifted—under the most trying conditions—a small part of a degree, and longitudinally there was no change.

In comparing the direction of the balloon drifting freely before the wind, with the direction given to it when the screw was in operation, it was found that the resultant made with the normal direction an angle of 12 deg. It is stated also that the speed given to the balloon, with $27\frac{1}{2}$ revolutions of the screw was $6\frac{1}{3}$ miles an hour, whilst the rate due to the wind alone was from 26 to 37 miles an hour.

With the same weight for a mechanical motor as that required by the eight men for driving the screw, a force ten times as great might have been obtained, and the speed due to the balloon under such improved conditions would be 13.60 miles per hour. With such a power it would apparently be practicable not only to make a considerable angle with the wind's direction, but also under favorable circumstances to shape the course of the balloon according to will.

ON THE THEORY OF THE STEAM ENGINE.*

UNITS OF MEASUREMENT.—PHYSICAL PROPERTIES OF STEAM.

1. From the principle that heat and work are mutually convertible, it follows that quantities of heat may be expressed in foot pounds, and conversely, that quantities of work may be expressed in thermal units. In thermo-mechanical questions it is necessary to have a common unit of measurement for heat and work, and in Rankine's work the foot pound has been adopted, but the thermal unit might likewise have been adopted, in which case quantities of work would be expressed in thermal units by dividing by 772: thus, 1-horse power is represented by $\frac{33000}{772}$ or 42.75 thermal units per minute. This mode of measurement possesses the advantage of leading to smaller numbers than the other; but, nevertheless, it will be seen herafter that the foot pound is the most convenient unit.

In measuring temperature we employ Fahrenheit's scale as the one in common use, although the centigrade scale is far more convenient, and it is to be hoped may ultimately be adopted.

2. The density of a vapor or gas is best measured by the volume which 1 lb. of it occupies, for which the convenient term "specific volume" is used by Zeuner. In the case of saturated steam the specific volume is given by the approximate formula $p v^{\frac{17}{16}}$ = constant, up to a pressure of 120 lbs. per sq. in. (Rankine, p. 403.) The elaborate calculations of Zeuner have fully confirmed this formula as representing with accuracy the density of steam as calculated from the relation existing between its latent heat of evaporation, temperature, and specific volume. According to him, the agreement (from .5 to 14 atmospheres) is almost exact, if the index 1.0646 be used in place of Rankine's index $\frac{17}{16} = 1.0625$. (Mechanische Warme Theorie, p. 294.) The value of the constant is about 475, if the pressures be in pounds per sq. in., and the volumes in cubic ft. If we employ Zeuner's index, the formula, when adapted to logarithmic computation, becomes

$$\log v = 2.516 - .939 \log p.$$

On account of the difficulty of obtaining steam in a perfectly dry and saturated condition, the density of steam can hardly be said to have been determined experimentally in a thoroughly satisfactory manner. The best experiments are those made by Fairbairn and Tate, who have given the following formula to represent them:—

$$v = .41 + \frac{389}{p - .35}$$

where v is the specific volume in cubic feet, and p is the pressure in lbs. per sq. in. This formula is very convenient in calculation, but can only be used for pressures between about 20 and 60 lbs. per sq. in. (absolute); below 20 its results are much too large, above 60 they are much too small. (Comp. Art. 24.)

The density of steam is likewise frequently measured by its "relative volume," that is, by the ratio which its volume bears to the volume of the water from which it was produced. To obtain the relative volume we have simply to multiply the specific volume by 62.5.

The complex relation between the temperature and pressure of saturated steam can only be expressed for a wide range of pressure by formulæ, such as that given by Rankine (p. 237), which require very tedious calculations. For pressures between 6 and 60 lbs. per sq. in. we may use the formula

$$p = \left(\frac{t + 40}{147}\right)^5$$

where p is the pressure in lbs. per sq. in., and t is the temperature Fahrenheit. From 60 to 120 lbs. per sq. in. this formula may likewise be used, but unity should then be added to the result.

Rankine has given a table of the pressure corresponding to a given temperature, but the table unfortunately only extends to every 9 deg. F. For the convenience of students a table is subjoined of the temperature corresponding to a given pressure for every pound on the sq. in., from 1 to 120. Fuller tables in English measures, which appear accurate so far as the writer has been able to examine them, will be found in "Porter on the Richards

* Notes of the Theory of the Steam Engine, being part of a course of instruction, in the subject given in the Royal School of Naval Architecture and Marine Engineering by James H. Cotterill. London, E. & F. N. Spon.

Indicator." The diagram recently published by Rankine is likewise convenient for obtaining the pressure and specific volume corresponding to a given temperature.

Table of the Temperature of Saturated Steam Corresponding to a Given Pressure.

P.	$t°$.	P.	$t°$.	P.	$t°$.
1	102	41	269	81	313
2	126	42	270	82	314
3	142	43	272	83	315
4	153	44	273	84	315
5	162	45	275	85	316
6	170	46	276	86	317
7	177	47	277	87	318
8	183	48	278	88	319
9	188	49	280	89	319
10	193	50	281	90	320
11	198	51	282	91	321
12	202	52	284	92	322
13	206	53	285	93	323
14	210	54	286	94	323
15	213	55	287	95	324
16	216	56	288	96	325
17	220	57	289	97	326
18	223	58	291	98	326
19	225	59	292	99	327
20	228	60	293	100	328
21	230	61	294	101	329
22	233	62	295	102	329
23	236	63	296	103	330
24	238	64	297	104	331
25	240	65	298	105	331
26	242	66	299	106	332
27	244	67	300	107	333
28	246	68	301	108	333
29	248	69	302	109	334
30	250	70	303	110	335
31	252	71	304	111	335
32	254	72	305	112	336
33	256	73	306	113	337
34	258	74	307	114	337
35	259	75	308	115	338
36	261	76	309	116	339
37	263	77	309	117	339
38	264	78	310	118	340
39	266	79	311	119	341
40	267	80	312	120	341

3. The specific heat of water increases slowly with the temperature, as is shown by the formula (1), page 246. It is usually supposed unity, but at high temperatures the error in doing so is not inconsiderable; thus, at a temperature of 400 deg. F., corresponding to a pressure of 250 lbs. per sq. in., the specific heat of water is 1.04; and at a temperature of 300 deg., corresponding to 67 lbs. per sq. in., it is 1.02. Where accuracy is required, it therefore cannot be assumed unity at high pressures.

4. The total heat of evaporation of water from 32 deg. at t deg. is given by the formula.

$$\text{Total heat} = 1091.7 + .305\ (T° - 32°)\ \text{(thermal units.)}$$
$$= 1082 + .305\ T°$$

or

$$H = 835{,}300 + 235.46\ T°\ \text{(in foot pounds).}$$

which formulæ represent with accuracy the results of Regnault's experiments.

The formula commonly used for the latent heat of evaporation, namely,

$$l = 966 - .7\ (T° + 212)\ \text{(in thermal units)}$$

assumes that the specific heat of water is unity at all temperatures. If great accuracy is required at high pressures, Rankine's tables should be used, the interpolation in which, for temperatures intermediate to those given in the table, in this case presents no difficulty.

It will be seen hereafter that the quantity of heat necessary to produce 1 lb. of steam from 1 lb. of water depends upon the way in which the steam is produced; it must, therefore, always be carefully remembered that the terms, "total heat of evaporation," "latent heat of evaporation," are conventionally restricted to the case where the steam is formed under *constant pressure.*

5. The external work done in turning 1 lb. of water, at a given temperature, into saturated steam at the same temperature, is $p\ (v—s)$ foot pounds, where v is the volume of steam produced in cubic ft., p the pressure in lbs. per sq. ft., and s the volume of 1 lb. of water or .016 cubic ft. In practice, s is usually neglected, the error so produced being only .8 per cent. at pressure of 226 lbs. per sq. in., and much less at lower pressures. When necessary, it is easy to take into account by subtracting .016 from the given value of v.

The calculation of pv, especially for pressures intermediate between those given in Rankine's tables, is troublesome, and hence a shorter method is desirable. If saturated steam conformed to the perfectly gaseous laws, pv would be given by a formula of the form

$$p\ v = a\ (461 + t)$$

where a is a constant.

On trial, however, it appears that, except at very low pressures, the errors of this formula are too great to render it of practical use: and if we modify it, writing

$$p\ v = A + B\ t$$

where A and B are two constants determined by trial, the same is true at temperatures above 212 deg. Zeuner, however, proposes the formula

$$\text{External work} = p\,(v-s) = A + B\,t - h$$

where A and B are constants determined by trial, and h is the heat (in foot lbs.) required to raise the temperature of 1 lb. of water from 32 deg. to t deg., a quantity given in Rankine's tables in the column headed h. If the specific heat of water, were unity at all temperatures, this formula would be of the same form as the last, h being 772 (t deg.—32 deg.); in fact, however, h increases more rapidly than this, and his quicker increase appears on trial very approximately to balance the errors of the original formula.

If we take A=15,450 (a value somewhat less than that which coresponds to Zeuner's value) and B=846, the formula becomes

$$\text{External work} = 15{,}450 + 846\,t - h$$

which, as far as the writer has been able to examine it, agrees well with the results derived from Rankine's tables. This formula is very convenient in calculation, as the value of h is readily interpolated for temperatures intermediate to those given in the table. For temperatures below 212 deg. we may write for h, its approximate value 772 (t–32), and thus obtain

$$\text{External work} = 74\,(542+t).$$

A still more convenient formula is derived from the formula given in Art. 2 for the density of steam. Supposing the pressure given in pounds per sq. in., and the product pv in foot pounds, we have

$$\text{Log}\,(p\,v) = 4\,.675 + .061\ .\ \log p.$$

The results derived from this formula are sufficiently accurate at all ordinary pressures.

CYCLE OF OPERATIONS.—INTERNAL WORK.

6. The principle of the "cycle of operations" is usually stated in the following form. Let a substance change its temperature and volume (or more generally its molecular condition) from some given state, and, passing through a complete cycle of such states, return to its original state; then the difference between the whole heat absorbed by the substance in one part of the process, and the whole heat rejected by the substance in another part of the process, is equal to the external work done by the body during the process. For example, let a pound of water be forced into a boiler, there evaporated, then pass through the engine into the condenser, and finally, after rejecting heat into the injection water, become once more water of the same temperature as before; then the difference between the heat absorbed in the boiler and rejected in the condenser by that pound of water, is equal to the effective work done by the engine per pound of steam.

This is a primary axiom of the mechanical theory of heat, evidently true on the supposition of the convertibility of heat and work, because no other effect has been produced, except the external work, the substance being in the same state as before by hypothesis. Its application, however, is easier when it is put in a different and somewhat more simple form. Let the substance change from a state A to a state B, and let Q_1 be the heat expended, U_1 the external work done during the change; let it now change back from B to A by a different set of changes, and let the heat rejected by the substance be Q_2, and the work done upon it by external bodies be U_2, then, by what has been stated above,

$$Q_1 - Q_2 = U_1 - U_2$$

but Q_2 and U_2 are exactly the heat which would have been expended, and the work which would have been done if the substance had changed from A to B by the *second route reversed;* hence, writing the equation in the form

$$Q_1 - U_1 = Q_2 - U_2$$

we see that the principle may be put in the form—

If, from the whole heat requisite to produce a given change of state, the equivalent of the external work be subtracted, then the remainder is always the same in whatsoever way the change is produced.

This form of the principle is in Rankine's work (see p. 304) deduced as a corollary from a different proposition, but it appears to be a necessary conclusion from the original form of the principle (at least whenever some way exists of passing from the state A to the state B, which is capable of being reversed), and it is, in fact, so assumed explicitly or implicitly by other writers. Indeed, it may not be questioned whether this form of the principle has not as much claim to be considered axiomatic as the other.

To take an example: Water at a temperature of 32 deg. requires about 904,000 foot pounds of heat to raise its temperature to 293 deg. F and to evaporate it at that temperature, which corresponds to a pressure of 60.4 lbs. per sq. in., or about 8,700 lbs. per sq. ft. Its volume is then very nearly 7 cubic feet, and the external work done very approximately 60,900 foot lbs. Subtracting this from 904,000 foot lbs. we get as a remainder 843,100 foot lbs. But now let us suppose that we produce our steam without doing external work. This may be very easily done; we have only to place our pound of water at 32 deg. in a close vessel, the capacity of which is 7 cubic ft., and apply heat till all the water is evaporated; we shall then have a pound of saturated steam at the temperature of 293 deg. F. as before, but we shall have done no external work, and the heat expended is therefore no longer 904,000 foot lbs., but 843,100 foot lbs.

We have, in fact, in the second case produced the steam and the steam only, while in the first case we have not only produced the steam, but we have also produced 60,900 foot lbs. of mechanical work, and the whole heat expended is separable into the two parts necessary to produce each effect separately.

So it is in the most general case; we must always separate the external and visible work done on external bodies from the internal and invisible work done in changing the state of the body. The second part, which we shall call the internal work, is always the same, however the change is produced.*

In some important cases the body is in motion, and in this case, in applying the principle, any change of kinetic energy must be taken into account. (Comp. Art. 36.)

The authorities on thermo-dynamics do not place the principle considered in this article in the same rank as the principle of the convertibility of heat and work, which is the first principle of the mechanical theory of heat, and the "second principle," which we shall have to consider hereafter. The reason of this apparently is, that it partakes rather of the nature of an axiom than of an experimental law. It is nevertheless admitted by all writers, and the conception by Carnot of a cycle of operations was the first step to a true theory of heat engines.

7. If we separate, in the manner just explained, the latent heat of evaporation of water into two parts, the internal work and the external work, and if we assume for the external work the formula given in 5, namely:

$$\text{External work} = 15{,}450 + 846\,t - h$$

we shall obtain a very simple formula for the internal work, for evidently

$$\begin{aligned}\text{Internal work} &= \text{Latent heat} - \text{external work}\\ &= \text{Latent heat} + h - 15{,}450 - 846\,t\\ &= H - 15{,}450 - 846\,t.\end{aligned}$$

This internal work may also be called the internal latent heat of evaporation, and, if the term latent heat had been invented after the discovery of the mechanical theory of heat, might very probably have been called simply the latent heat. If we denote it by ρ, then replacing H by its value,

$$\begin{aligned}\rho &= 819{,}850 - 611\,t \text{ (foot pounds)}\\ &= 1{,}062 - .79\,t \text{ (thermal units).}\end{aligned}$$

PRESSURE EQUIVALENT TO THE EXPENDITURE OF HEAT—ENGINE WORKING WITH DRY SATURATED STEAM.

8. If A be the area of a piston, κ the space through which it moves, and p the pressure upon it, then $p\,A\,\kappa$ is the work done. Let now $A\,\kappa = 1$, that is, let the piston sweep through 1 cubic foot, then the work is simply p, the pressure supposed expressed in lbs. per sq. ft. Thus the pressure on a piston in lbs. per sq. ft. may also be considered as the work done per cubic foot swept through by the piston. But we can easily find the heat expended by an engine per cubic foot swept through by the piston, and when expressed in foot pounds, it follows that it may be regarded as a "pressure equivalent to the expenditure of heat," and by division by 144, it may be expressed in lbs. per sq. in.

This mode of expressing the expenditure of heat in an engine, was introduced by Rankine, and is far more convenient

* The expression "internal work" has been hitherto more often used in a different sense; the remainder spoken of in the ennunciation is separated into two parts, one of which is described as the heat necessary to produce change of temperature, and the other as the heat necessary to produce change of molecular position, for which second part the term "internal work" has been appropriated. (See, for instance, Tait's "Thermo-dynamics," Art. 46.) But this distinction does not appear to us a useful one, at least at the outset of the subject; the student is thereby compelled to form some hypothesis as to the constitution of matter, whereas "internal work," as defined in the text, is evidently capable of exact definition without any hypothesis at all. We have, therefore, followed Zeuner in his use of the word without entering (as Zeuner does) on the above distinction.

than any other; for once knowing the pressure equivalent to the expenditure of heat, we obtain the actual expenditure of heat in exactly the same way as we obtain the power of the engine from the mean effective pressure; and, for this reason, the foot pound is a more convenient unit of measurement in the theory of the steam engine than the thermal unit.

In a non-expansive engine, working with dry saturated steam, the pressure equivalent to the expenditure of heat is easily found as follows:

Let H be the total heat of evaporation of water *from* the temperature of the feed-water *at* the temperature of the boiler, v_1 be the specific volume of the boiler steam, then H_1 is the heat expended for every pound of steam, and consequently $\frac{H_1}{v_1}$ for every cubic foot of steam admitted into the cylinder; but for every cubic foot of steam admitted, the piston sweeps through one cubic foot, hence it follows that where p_h is the pressure required.

$$p_h = \frac{H}{v_1} \text{ (lbs. per sq. ft.)}$$

9. If from the heat expended in an engine we subtract the work done, we get the heat rejected, and hence if p_r be the pressure equivalent to the heat rejected,

$$p_r = p_h - (p_1 - p_3) = \frac{H_1}{v_1} - (p_1 - p_3)$$

in the case of the non-expansive engine, p_3 being supposed the back pressure.

10. Let us now take the case of an expansive engine working with dry saturated steam, and find the pressure (p_h) equivalent to the expenditure of heat. This may be done in two ways, both involving essentially the same principle.

First Method.—Let the pressure be at admission p_1, at the end of the expansion p_2 and let the corresponding specific volumes be v_1 v_2; then at the end of the stroke we have by hypothesis a cylinder full of dry saturated steam of the pressure p_2, which at exhaust rushes into the condenser (or atmosphere), and is there condensed. Let us now imagine a non-expansive engine working *at pressure* p_2, with the same back pressure p_3; at the end of *its* stroke we shall have a cylinder full of dry saturated steam, which at exhaust will rush into the condenser (or atmosphere), and there be condensed. And *since the circumstances of the condensation are the same*, the heat rejected will be the same in the two cases, that is,

$$p_r = \frac{H_2}{v_2} - (p_2 - p_3)$$

where H_2 is the total heat of evaporation *from* the temperature of the feed-water *at* the temperature corresponding to p_2, the final pressure.

Let now $p_m - p_3$ be the mean effective pressure, then the work done by the engine for every cubic foot swept through by the piston is $p_m - p_3$ and hence, since

Heat expended = heat rejected + work done.

$$p_h = p_r + p_m - p_3 = \frac{H_2}{v_2} + p_m - p_2.$$

Second Method.—But we can also reason thus:

Each pound of the steam at the end of the stroke is dry saturated steam of pressure p. However that steam is produced, we must always have

Heat expended = Internal work + External work,

of which two terms the Internal work is always the same, while the External work is the energy exerted by the steam on external bodies during its formation. Now if that steam be formed by the ordinary process of evaporation at constant pressure p_2, then the heat expended will be H_2 the total heat of evaporation *from* the temperature of the feed-water *at* the temperature of evaporation, and we have, therefore, for every pound of steam,

$$\text{Internal work} = H_2 - p_2 v_2$$

but the steam is actually formed by a complex series of changes, such that, instead of overcoming the uniform pressure p_2, it presses on the piston with mean pressure p_m, and exerts on that piston for every poundof steam the energy $p_m v_2$.

$$\therefore \text{Heat expended} = H_2 - p_2 v_2 + p_m v_2 \text{ (per lb.)}$$

and the heat per cubic foot swept through by the piston is given by

$$p_h = \frac{H_2}{v^2} + p_m - p_2 \text{ (as before).}$$

The reader shonld notice that the energy exerted by each pound of steam, namely $p_m v_2$, may be separated into two parts, of which one $(p_m\ p_3)v_2$ is employed in overcoming external resistance, and the other $p_3\ v_2$ is expended in work done upon the condensing steam, and reappears in the form of heat in the condenser.

11. The engine being supposed working

with dry saturated steam, the equation to the expansion curve is $pv^{\frac{17}{16}}$=constant, from which, if the ratio of expansion be given, the final pressure p_2, and the mean forward pressure p, are readily determined.

It will not, however, be possible that the steam should be dry and saturated during the expansion, unless heat be supplied by means of a steam or hot-air jacket while the expansion is going on. For suppose the boiler to supply dry saturated steam, then the heat required to produce it will be represented by

$$p'_h = \frac{H_1}{v_2}$$

for H_1, the total heat of evaporation *from* the temperature of the feed-water *at* the temperature of the boiler, is the heat expended in the boiler per lb. of steam, and therefore $\frac{H_1}{v^2}$ is the heat expended in the boiler per cubic foot swept through by the piston, or p'_h is the pressure equivalent to the heat expended in the boiler. But p_r is greater than p'_h, for

$$p_h = \frac{H_2}{v_2} + p_m - p_2$$

$$\therefore p_h - p'_h = \frac{H_2 - H_1}{v_2} + p_m - p_2$$

$$= p_m - p_2 - \frac{235\ (t_1 - t_2)}{v_2}$$

and it will be found on trial that the expression on the right hand side is always positive Evidently $p_h - p'_h$ represents an amount of heat which must be supplied to the steam elsewhere than in the boiler, and if this be not done, the steam cannot be dry at the end of the stroke, but condensation must take place.

When a steam or hot-air jacket exists, moist steam absorbs heat with great rapidity from the hot sides of the cylinder, and experience appears to show that the steam is really prevented from condensing in this way. On the other hand, when the steam is once dry it absorbs heat very much more slowly, and there is consequently good foundation for the supposition that, when the cylinder is jacketed, the steam is dry and saturated during the expansion. But when the cylinder is not jacketed and the steam is not superheated before it enters the cylinder, then condensation necessarily takes place, even though the cylinder be so well clothed that there is no sensible radiation from its external surface.

The heat produced by friction of the cylinder no doubt modifies this statement to a certain extent. The amount of piston friction is variable and uncertain, but we suppose it much overestimated in normal circumstances, if we take it as 1 lb. per sq. in.; this 1 lb. per sq. in. diminishes the pressure equivalent to the expenditure of heat by the same amount, but such diminution is not sufficiently sensible to reduce the condensation.

Nevertheless the reader must bear in mind that this conclusion is based solely on numerical calculations from the formula just given, and if a different fluid than water were used might not be true. For example, in the case of ether, it is believed that super-heating, and not condensation, would take place.

12. The formula just now given for the pressure equivalent to the expenditure of heat

$$p_h = \frac{H_2}{v_2} + p_m - p_2$$

is true whether or not the steam is dry and saturated at other times, provided only that it is so at the end of the stroke. With this restriction the treatment of the steam may be anything we please ; it may contain suspended water, or it may be superheated, the formula will still be true. The value of p_m of course will be different in each case, but when p_m is known from an indicator diagram or otherwise, p_h can always be determined, We shall consider this further hereafter.

13. By use of the formula given in 5 for pv

$$p\,v = 15{,}450 + 846\,t - h$$

we can put the formula for p_h in a form in which the calculations from it are very simple. For

$$p_h = \frac{H_2}{v_2} + p_m - p_2$$

$$= p_m + p_2\left(\frac{H_2}{p_2\,v_2} - 1\right).$$

Now let t_4 be the temperature of the feed-water, then

$$H_2 = 772\ (1082 + .305\ t_2) - 772\ (t_4 - 32)$$

Also, since t_2 is never a high temperature, we may put very approximately

$$h = 772\ (t_2 - 32).$$

Therefore we have

$$\frac{p_2 v_2}{772} = \frac{15{,}450+846\,t_2}{772} - (t_2 - 32)$$
$$=52+.096\,t_2.$$
$$\therefore \frac{H_2}{p_2 v_2} = \frac{1{,}114+.3\,t_2 - t_4}{52+.096\,t_2}.$$
$$\therefore p_h = p_m \frac{1{,}062+.21\,t_2 - t_4}{52+.096\,t_2} p.$$

The formulæ given by Rankine are

$p_h = p_m + 15\,p_2$ (for condensing engines)

$p_h = p_m + 14\,p_2$ (for non-condensing engines)

agreeing well with the results of the foregoing mere general formula. These formulæ are very simple and convenient in calculation, as p_m and p_2 do not require to be expressed in pounds per square foot, as they must be in the orginal form of the formula.

It is, however, necessary to know p_2 with great accuracy, any error being multiplied by 15 or thereabouts produces an error in p_h some 15 times as great as an equal error in p_m.

THERMO-MECHANICAL PROPERTIES OF THE PERMANENT GASES.

14. If $p\ v\ p^1\ v^1$ be the pressure and specific volume of air at two temperatures $t\ t^1$, measured by Fahrenheit's scale *on the air thermometer*, it is known that very approximately

$$\frac{p\,v}{p^1 v^1} = \frac{461+t}{461+t^1} *$$

It is likewise known that this relation is very approximately true of all other permanent gases, that is, gases which have not yet been liquefied by application of cold and pressure; while, on the other hand, it is less approximately true of gases which are capable of liquefaction, such as carbonic acid. Thus, it is easy to conceive an ideal gas for which this relation is mathematically correct, which ideal gas may be considered as a perfect gas, just as from the properties of water we conceive a perfect fluid, although, in fact, no such thing actually exists.

The above equation represents, then, a relation always existing between the pressure volume and temperature of a perfect gas. It may be written in the form

$$p\,v = \frac{p^1 v^1}{461+t^1}(461+t)$$

* The numbers given may probably require slight alterations not exceeding 1-200th part, but the certainty and importance of the alterations are not sufficient to render it necessary to depart from the values as given by Rankine.

or

$$p\,v = c\,T$$

where c is a constant which for air has the value 53.15, and T is the† temperature measured by Fahrenheit's scale on a perfect gas thermometer, from a zero 461 deg. below the zero of Fahrenheit's scale, or 493 deg. below the freezing point of water. Evidently the value of c will be proportional to the density of the gas at some given pressure and temperature.

Again, if air be heated at constant pressure through 1 deg. F. measured on the air thermometer, it is found that the quantity of heat absorbed by each pound of the air is very approximately .2375 thermal units, or 183.35 ft. bls., whatever be the pressure or temperature of the gas; in other words, its specific heat at constant pressure when measured in foot pounds is always 183.35. So also it is found that the specific heats at constant pressure of the other permanent gases are always the same, and are, moreover, proportional to their densities, that is, proportional to c very approximately. We are thus led to conclude that these laws are characteristic of the perfectly gaseous state.

Lastly, it is known that the same laws hold good with respect to the specific heat at constant volume of air, and that the ratio of the specific heat at constant pressure to the specific heat at constant volume is 1.408, so that the actual value of the specific heat at constant volume is $\frac{183.35}{1.408} = 130.2$. It is true that at present the difficulties of experimenting directly on the specific heat at constant volume of gases have not been overcome, and that the experiments on the ratio of specific heats give discordant results; but for our present purpose there seems no impropriety in assuming the known result, as it will be seen presently we have two independent means of testing the truth of the supposition.

We now observe that the difference of the two specific heats of air is 53.15, that is, it is equal to c; further, as just stated, the specific heat at constant pressure of all permanent gases is proportional to c. We are hence led to the conclusion that, if K_p K_v be the specific heats (expressed in foot pounds) of a perfect gas at con-

† By absolute temperature we mean at present simply temperature measured in this way.

stant pressure and constant volume respectively, we must always have

$$K_p - K_v = c$$

as a mathematically exact relation satisfied very approximately by the actual permanent gases.

15. We can now obtain a very important result, namely, that the heat expended in internal work, when any change of state is produced in a perfect gas, is simply $K_v\ (t_1 - t_2)$ where $t_2\ t_1$ are the temperatures at the beginning and end of the change.

For let $p_2\ v_2\ p_1\ v_1$ be the corresponding pressures and volumes of the gas: and let us by application of heat change the volume of our gas from v_2 to v_1, the pressure remaining constantly p_2, then by definition

$$\text{Heat expended} = K\ (t - t_2)$$

where t is the new temperature. Also

$$\text{External work done} = p_2\ (v_1 - v_2)$$
$$= c\ (t - t_2)$$
$$\therefore \text{Internal work} = (K_p - c)\ (t - t_2$$
$$= K_v\ (t - t_2.$$

Next let the pressure be changed from p_2 to p_1 at the constant volume v_1 attained by the first operation; then by definition,

$$\text{Heat expended} = K_v\ (t_1 - t)$$

and in this case no external work is done, and

$$\therefore \text{Internal work} = K_v\ (t_1 - t)$$

Add together the two values of the internal work, and we get $K_v\ (t_1 - t_2)$ as the internal work done in changing from the original state to the final state.

But this internal work, by the principle of Art. 6, is the same in every case, hence the proposition is true.

Let us now test the truth of this result by the following experiment:–

Air is contained in a vessel which communicates by a pipe furnished with a stop-cock with another vessel, in which a very perfect vacuum exists, or else which contains air of exactly the same temperature but of a different pressure. The stop-cock being opened, air rushes from one vessel to another; after a time the motion ceases, and the temperature is found to be very slightly altered.

This experimental result confirms the truth of what has been stated, for in passing from one vessel to the other no heat is expended on the air, and no external work is done, therefore the change of internal work must be zero; that is, if our proposition is true, the temperature is unaltered.

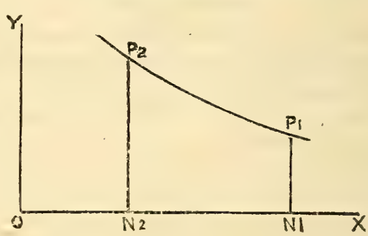
When non-permanent gases are experimented on, the temperature is found to be sensibly changed.

In our mode of statement this experimental result is the first confirmation of the value assumed for the specific heat of air, at constant volume. Indeed, it is possible hence to prove, by reasoning analogous to that given above, that the specific heat, at constant volume of air, must have the value assumed by us and no other.

16. We can now find the heat expended in producing any change in a pound of air, for

$$\text{Heat expended} = \text{internal work} + \text{external work}$$
$$= K_v\ (t_1 - t) + \text{external work}$$
$$= K_v \cdot \frac{p_1\ v_1 - p_2\ v_2}{c} + \text{external work}$$

which is the general equation of the action of heat in a perfect gas. We may represent this geometrically thus: Drawing a dia-



gram in which as usual ordinates represent pressures and abscissæ represent volumes; let $P_2\ N_2$, $O\ N_2$ be the initial pressure and volume, $P_1\ N_1$, $O\ N_1$ the final pressure and volume. Then the area $P_2\ P_1\ N_1\ N_2$ represents the work done by the expansion of the gas, where $P_1\ P_1$ the expansion curve is perfectly arbitrary, and may be anything we please, if heat be applied according to a proper law. The actual expenditure of heat is geometrically represented by

$$\frac{K_v}{c}(\text{rectangle } P_1\ N_1 . ON_1 - \text{rectangle } P_2\ N_2\ . ON_2)$$
$$+ \text{ area } P_2\ P_1\ N_1\ N_2$$

There are two important cases—

First, let the expansion take place at constant temperature, we then have

$$\text{Heat expended} = \text{Area } P_1\ N_1\ N_2\ P_2\ ;$$

but the expansion curve is then a common hyperbola, the asymptotes of which are O X O Y. Then, the area

$$P_1\ N_1\ N_2\ P_2 = P_1 N_1 . O\ N_1 \log \frac{O\ N_1}{O\ N_2}$$

the logarithm being hyperbolic,

$$\therefore \text{ Heat expended} = p_1 v_1 \cdot \log r$$
$$= c\,T \log r$$

where r is the ratio of expansion and T is the absolute temperature.

Secondly, let the gas expand in a non-conducting non-radiating cylinder; that is, let it expand without gain or loss of heat, then the expansion curve is a curve called the adiabatic curve, the form of which we require to find. Evidently we have

$$\frac{K}{c}\,(p_2 v_2 - p_1 v_1) = \text{Area } P_1 N_1 N_2 P_2$$

By the aid of the differential calculus, we easily find that the curve possessing this geometrical property, is given by the equation

$$p\,v^{\gamma} = \text{constant}$$

where $\gamma = \frac{K_p}{K_v}$. This, then, is the equation of the adiabatic curve.

An interesting result has been arrived at by Zeuner, of which this is a particular case; it is easy to show that, if the pressure and volume change in such a way that the specific heat is a constant quantity κ, then they must satisfy the equation

$$p\,v^n = \text{constant}.$$

where $n = \frac{K - K_p}{K - K_v}$: the adiabatic curve is the special case in which $K = o$.

From the form of the adiabatic curve is obtained a second experimental confirmation of the properties of the specific heat at constant volume assumed in 14; for it can be shown that very approximately the velocity of sound in a gas, when the adiabatic curve is of this form, must be

$$\sqrt{g\,\gamma\,c\,T}.$$

(Compare Rankine's Art. 252.)

When a gas expands without gain or loss of heat, its temperature falls. For suppose it expands from v_1 to v_2, and let its pressure and temperature then be p_1, T_1 and p_2, T_2, then we have

$$p_1 v_1 = c\,T_1\ ;\ p_2 v_2 = c\,T_2\ ;\ p_1 v_1^{\gamma} = p_2 v_2^{\gamma}.$$
$$\therefore c\,T_1 v_1^{\gamma - 1} = c\,T_2 v_2^{\gamma - 1}$$

or

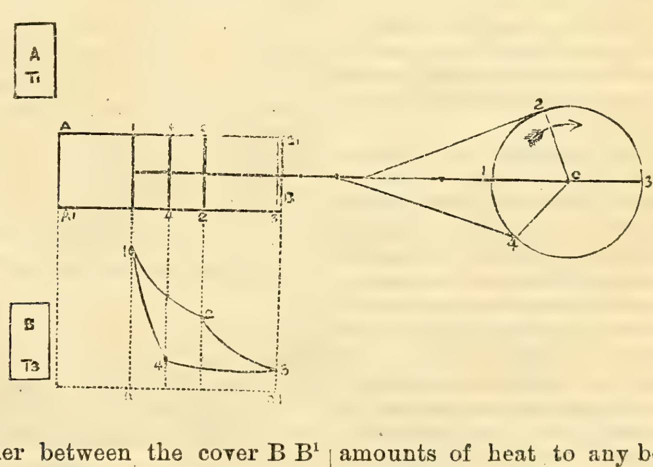
$$T_2 = T_1 \cdot \left(\frac{1}{r}\right)^{\gamma - 1}$$

where r is the ratio of expansion, a result which shows that the temperature falls, and enables us to find by how much it has fallen.

THEORY OF A HEAT ENGINE WORKING WITH A PERFECT GAS—CONDITIONS OF MAXIMUM EFFICIENCY.

17. The simplest kind of heat engine is constructed as follows:

A B is a working cylinder containing a given quantity, say 1 lb., of a perfect gas always included between the cylinder cover A A^1 and a piston, successive positions of which are represented in the figure by 11, 22, 33, 44, and which may be supposed connected in the usual way with a crank, corresponding positions of which are O_1 O_2 O_3 O_4. The right hand portion



of the cylinder between the cover B B^1 and the piston is empty.

A and B are two bodies capable of communicating or abstracting indefinite amounts of heat to any body placed in contact with them and of temperatures (absolute) T_1 and T_3 respectively.

Suppose the crank moving in the direction of the arrow, and initially let it be in the position O_1, and let the pressure volume and temperature of the gas be then p_1 v_1 T_1 respectively. Then, as the crank moves on, the volume of the gas increases, and if no heat were applied to it the temperature would fall; but this is prevented by placing the body A in contact with the cylinder, which is to be supposed a perfect conductor, so that the slightest depression of the temperature of the gas below T_1, causes heat to flow from A into the gas, and thus the temperature of the gas is maintained constantly at T_1. During this first operation, then, the gas expands at constant temperature, and the expansion curve 1, 2 in the indicator diagram above, is a common hyperbola.

The expansion having reached some convenient point 2, the body A is to be removed from the cylinder, so that no more heat is received by the gas; its temperature then falls, instead of remaining constant, and the expansion curve 2, 3 on the indicator diagram above, is now an adiabatic curve given by $pv\gamma$=constant. This goes until the piston has reached the end of its stroke and begins to return to compress the air again, and raise its temperature according to the same law by which it fell during the expansion. But this rise of temperature is prevented by the application of the body B, the temperature of which is T_3, the temperature of the gas at the end of the stroke, and which abstracts heat from the gas the instant its temperature rises above T_3.

Thus the gas is compressed at constant temperature T_3, and the compression curve 3, 4 on the indicator diagram given on preceding page, is a common hyperbola.

This compression goes on till the piston reaches a point 4, the position of which will presently be determined when the body B is removed and the temperature of the gas allowed to rise. The gas is then compressed without gain or loss of heat, so that the compression curve 4, 1 on the indicator diagram given on the preceding page, is an adiabatic curve. If now the point 4 has been properly taken, the temperature of the gas at the end of the stroke will be T_1, and the gas having returned exactly to its initial state, the process may be repeated as many times as we please.

The required point 4 is easily found thus: let p_2 v_2 p_3 v_3 p_4 v_4 be the pressure and volume at the points 2, 3, 4, then since 1, 2, and 3, 4 are common hyperbolas

$$\frac{p_1}{p_2} = \frac{v_2}{v_1} \text{ and } \frac{p_3}{p_4} = \frac{v_4}{v_3}$$

and since 2, 3, and 4, 1 are adiabatic curves

$$\frac{p_2}{p_3} = \left(\frac{v_3}{v_2}\right)^\gamma \text{ and } \frac{p}{p_1} = \left(\frac{v_1}{v_4}\right)^\gamma$$

Hence multiplying all four equations together.

$$v_1\ v_3 = v_2\ v_4 \text{ or } \frac{v_2}{v_1} = \frac{v_3}{v_4}$$

or—*the ratio of expansion during the reception of heat must be equal to the ratio of compression during the rejection of heat,* or since we equally have

$$\frac{v_3}{v_2} = \frac{v_4}{v_1}$$

—*the ratio of adiabatic expansion must be equal to the ratio of adiabatic compression.* It is easily seen that each of these last ratios must be equal to $\left(\frac{T_1}{T_3}\right)^{\frac{1}{\gamma-1}}$, which determines their value when the temperatures T_1 T_3 of the bodies A and B are supposed given.

Let us now examine how much work is done by this engine, and at what expenditure of heat.

During the operation 1, 2 the gas is receiving heat from A, and the quantity of heat it receives according to the last article is

$$Q = c\,T_1 \log r$$

where r is the ratio of expansion. During the operation 2, 3 which completes the forward stroke, the gas receives no heat, therefore Q is the heat expended in the forward stroke. At the same time the energy exerted on the piston by the gas is represented by the area 1, 2, 3, n^1 n.

In the backward stroke the gas rejects the heat into B, and the heat so rejected is

$$R = c\,T_3 \log r$$

At the same time the piston compresses the gas and does work upon it represented by the area 1, 4, 3 n^1 n; the engine, in fact, is single-acting and a fly-wheel will be required to carry it through the whole backward stroke.

The difference between these areas, namely, the area of the indicator diagram 1, 2, 3, 4, represents as usual the work done by the engine. We might calculate this area, but it is simpler to apply the principle of the cycle of operations, for since the gas returns exactly to its original pressure, volume, and temperature, we must have

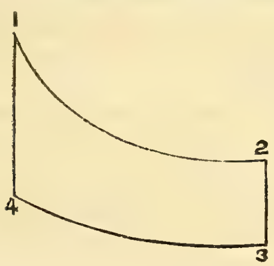
$$\text{Work done} = Q - R = c\,(T_1 - T_3) \log r.$$

The efficiency is now found from the consideration that the heat expended is Q,

$$\text{Efficiency} = \frac{\text{Work done}}{\text{Heat expended}} = \frac{T_1 - T_3}{T_1}$$

18. The simple heat engine just considered may be arranged to work in an indefinite number of other ways, one of which will now be considered as an example.

Let us suppose that the body A remains in contact with the cylinder throughout the forward stroke, and the body B throughout the backward stroke, the indicator diagram will now be as shown in the figure. 1 2 is an hyperbola as before, but now extends through the whole forward stroke, and 3 4 is also an hyperbola as before, but extending through the whole



backward stroke; but 1, 4, 2, and 3, are vertical straight lines representing the sudden rise of pressure on contact with the body A, and fall of pressure on contact with the body B, at the commencement of the forward and backward strokes respectively.

To find the efficiency of this arrangement we have, as before

$Q = c\,T_1 \log r =$ heat expended in forward stroke
$R = c\,T_2 \log r =$ heat rejected in backward stroke

and, as shown in 16, these quantities are also the works done upon the piston by the gas in the forward stroke, and upon the gas by the piston in the backward stroke,

$\therefore$ Work done by engine $= c\,(T_1 - T_3) \log. r$ as before.

but the whole heat taken away from A, that is, the whole heat expended, is now no longer Q, because at the commencement of the stroke a quantity of heat $K_v (T_1 - T_3)$ has to be expended in raising the temperature of the gas from T_1 to T_3, and we consequently have

$$\text{Heat expended} = Q + K_v (T_1 - T_3)$$
$$= c\,T_1 \log r + K_v (T_1 - T_3)$$

$$\text{Efficiency} = \frac{c\,(T_1 - T_3) \log r}{c\,T_1 \log r + K_v (T_1 - T_3)}$$

$$= \frac{T_1 - T_3}{T_1} \cdot \frac{1}{1 + \dfrac{K_v}{c \log r} \cdot \dfrac{T_1 - T}{T_1}}$$

Thus we see that the efficiency of this arrangement is less than that of the other, and we likewise see why it is so, namely, because at certain points in the process the gas has its temperature raised and lowered by contact with the bodies A and B, that is, *that it receives and rejects heat at temperatures sensibly different from the temperatures of A and B.*

There are two conceivable ways of avoiding this loss of efficiency: the first is by storing up the heat rejected during the cooling represented by 2, 3, and employing it to produce the rise of temperature represented by 4, 1. This has been done in actual air engines by the contrivance called the regenerator. (See Rankine, Art 268.) The second is by inserting an auxiliary heat engine receiving heat from the hot gas of the original heat engine after it has finished its work in that engine; the work of this auxiliary engine will be so much additional work done without any additional expenditure of heat.

19. We shall now show that by no possible arrangement, with or without the additions just now mentioned, can we obtain an efficiency greater than that obtained by the original arrangement. We might do this by examining each particular case, but we prefer to reason more generally, as follows:—

Returning to the figure of Art. 17, and suppossing initially the crank in the position O_1, let the engine turn in the opposite direction to that indicated by the arrow, neither A nor B being in contact, the gas will expand without gain or loss of heat, and the adiabatic curve 1, 4 will be described on the diagram. As soon as 4 is reached, let the body B be applied to prevent the temperature falling below T_1: heat is continually abstracted from B, the hyperbola 4_1 3 is described on the diagram. Now removing the body A, the piston returns, and the adiabatic curve 3, 2 is described; and, finally applying A to prevent the temperature rising above T_1, the hyperbola 2, 1 is described, heat all the while passing from the gas into A.

The whole process is now exactly the reverse of what it was; a heat R is abstracted from B, and a heat Q passes into A, while, instead of the engine doing work on external bodies, some force must be applied to the crank, which in each revolution will do the work Q—R. And thus, instead of heat passing from A to B, and during its passage a part of it being converted into mechanical energy, we have conversely, by application of mechanical energy, heat passing from B to A, and during its passage mechanical energy converted into heat. In short, the process is *reversible.*

Let us now imagine any other arrangement of this heat engine with or without the additions alluded to just now, and let heat expended be Q, the heat rejected R, and let $Q_1—R_1=Q—R$, that is, let the work done by this engine be equal to the work done by an engine of the original arrangement: and let us further suppose that this engine is employed to work the original engine backwards, a thing which we have just shown to be possible.

Now the efficiency of the one engine is $\frac{Q_1-R_1}{Q_1}$ and of the other $\frac{Q-R}{Q}$; hence, if the first be greater than the second we must have Q_1 less than Q. This, however, is impossible, for the one engine takes away a heat Q_1 from A, and adds a heat R_1 to B, while the other engine takes away a heat R from B, and adds a heat Q to A; the combined action of the two then takes away $Q_1—Q$ from A, and adds an equal quantity $R_1—R$ to B. Thus, if Q_1 be less than Q, heat passes from B to A, and this effect is produced without any expenditure of work, for the combined engines require no power to work them. But this is absurd, for we may take it as an axiom that—*Heat cannot be made to pass from a cold body to a hot one without the expenditure of mechanical energy.**

It will now be asked why we cannot work this combined engine in a reverse direction and thus show that the efficiency of all possible arrangements must be the same. The answer to this question is, that it is the original arrangement only which admits of being reversed, for in all the other arrangements heat passes from the bodies to the gas, or reversely, at temperatures differing sensibly from that of the bodies themselves, and this is a process which is incapable of being reversed.

For example, suppose the arrangement of Art. 18 worked backwards, instead of the heat $c\,T_3 \log r + K_v\,(T_1 - T_3)$ being taken away from B, and the heat $c\,T_1 \log r + K_v\,(T_1-T_3)$ being added to A, as would be the case if the process were exactly reversible, it will be found that the heat taken away from B will be $c\,T_3 \log r - K_v\,(T_1-T)$, and the heat added to A will be $c\,T_1 \log r - K_v\,(T_1-T_3)$; thus, the process not being reversible, the reasoning fails.

Since, then, no arrangement, even with the addition of a regenerator or auxiliary heat engine, can have a greater efficiency than the original, it follows that without these additions the efficiency must be less, and we finally arrive at the following important conclusions with respect to this kind of engine:

First.—The maximum efficiency is $\frac{T_1-T_3}{T_1}$ where T_1 T are the absolute temperatures of the bodies A and B.

Secondly.—The conditions of maximum efficiency of the simple engine are, that the gas shall receive heat at the constant temperature of the body A, and shall reject heat at the constant temperature of the body B. Or, to express the same thing differently, that the process should be *reversible.*

The reader who has followed us so far, will now, without much difficulty, be able to proceed further, and to perceive that our reasoning is of much wider application; while, on the other hand, some help is obtained in comprehending what has gone before by the more general considerations to which we now proceed.

SECOND PRINCIPLE OF THE MECHANICAL THEORY OF HEAT.—ABSOLUTE TEMPERATURE.

20. To produce mechanical power by means of heat, it is in the first place necessary that we should have bodies of different temperatures, for it is evident that if all bodies were of the same tem-

*Some writers prefer a different form of this axiom. (See Tait's "Thermo-Dynamics," Art. 58.

perature, we could no more produce any change by means of heat than we could do work by the action of gravity if all bodies were on the same level. Mechanical energy, then, is produced from heat by the transfer of heat from a hot body to a cold one, and the power of turning heat into work must depend in some manner on the difference of temperature between the hot body and the cold one.

This alone, however, is not sufficient, for if heat simply pass from a body A to a body B, without the intervention of a third body, not only is no mechanical work done, but all the power of turning heat into work due to the difference of temperature of A and B is permanently lost, because the heat is now in the body B and cannot be made to pass back to A.

If, however, we take a third body capable of changing its volume by application of heat, and cause it to receive heat from the hot body and reject heat into the cold body, so that heat is transferred from the hot body to the cold one by its agency, we are then able by means of the changes of volume of this intermediate body to convert a portion of the heat into mechanical energy. It is, however, easy to see that only a portion can be so converted, for it will be found on reflection that rejection of heat into a cold body is just as indispensable a part of the process as reception of heat from the hot body, and thus a part of the heat necessarily merely passes through the intermediate body without being converted into mechanical energy. Thus, in the steam engine, the hot body is the hot gas in the furnace, the cold body is the atmosphere or condenser, the intermediate body is water, and the condensation of the steam after it has done its work is just as necessary a condition that work should be done as the evaporation of the water in the boiler.

Thus, for the production of mechanical energy from heat, we must have a hot body, by a cold body, and an intermediate body, by the agency of which heat is transferred from the hot body to the cold one.

And since the power of turning heat into work is wasted whenever heat passes from a hot body to a cold one without the agency of an intermediate body, it follows that the process of transformation will be most efficient when the intermediate body has the same temperature as the hot body when receiving heat, and the same temperature as the cold body when rejecting heat. Let us, for instance, suppose that the intermediate body rejects heat at a temperature above that of the cold body, then evidently we can insert an auxiliary heat engine between the intermediate body and the cold body, by means of which a part of that rejected heat can be turned into mechanical energy, without abstracting any additional heat from the hot body. And again, if the intermediate body receives heat from the hot body at a temperature less than that of the hot body, it may evidently be supposed to do so through the agency of an auxiliary heat engine, which receives heat from the hot body and rejects it into the intermediate body, the effect of which is to increase both the work done and the heat expended by *equal* quantities, and thus to increase the efficiency of the process.

Thus we see that the conditions of maximum efficiency of all heat engines are the same as those of the simple kind of engine considered in previous articles.

And more than that, the value of the maximum efficiency must be the same, for it will be seen, on referring back to the last article, that the argument holds equally good if the engine working forwards have the same or a different intermediate body from the engine which is working backwards.

Thus the conclusions stated with reference to the simple engine hold good with reference to any possible heat engine, and these general conclusions constitute the "second principle of the mechanical theory of heat," which may be otherwise briefly stated thus :—

The efficiency of every reversible engine is $\frac{T_1 - T_3}{T_1}$ *and is greater than the efficiency of any other heat engine working between the same limits of temperature.*

21. Let us now imagine the temperature T_1 of the hot body, or source of heat, to be divided into n equal parts, and let us imagine a quantity of heat Q to flow from that body to a second body, the temperature of which is $T_1\left(1 - \frac{1}{n}\right)$, then our results show, that a quantity $\frac{Q}{n}$ of mechanical work is capable of being produced, and that consequently, if such conversion be effected, the quantity of heat $\frac{n-1}{n} \cdot Q$

will pass into the second body. Now imagine a third body, the temperature of which is $T_1\left(1-\frac{2}{n}\right)$ and let this heat pass from the second body to the third body; then the heat capable of being turned into work is

$$\frac{n-1}{n} \cdot Q \cdot \frac{T_1}{n} \cdot \frac{1}{T_1\left(1-\frac{1}{n}\right)}$$

that is $\frac{Q}{n}$ as before. This process may be continued indefinitely, and we thus see that—*If the temperature of a source of heat be divided into any number of equal parts, then the effect of each of these parts in causing work to be performed is the same.*

It is in this form that Rankine enunciates the "second principle," and his view may be illustrated by the analogy which exists between the difference of level, which causes work to be performed by an hydraulic machine, and the difference of temperature which causes work to be performed by a heat engine. Each foot of fall in a water-wheel is equally effective in doing work by means of the water-wheel, and just so each degree of temperature passed through during the passage of heat from a hot body to a cold one is equally effective in causing work to be done by a heat engine working by means of this heat.

The temperatures in question are, as our investigation shows, to be measured on the perfect gas thermometer, which is, therefore, entitled to be considered as a definite measure of temperature. Temperature, being by its nature incapable of direct measurement, we can only measure it by considering some physical effect which difference of temperature produces; thus the ordinary mode of measurement is, by observing the expansion which bodies undergo when their temperature is raised. This, however, is inconvenient for scientific purposes, since no two thermometers give exactly the same results; for instance, the mercurial and air thermometers, if graduated to indicate correctly the temperatures of melting ice and of water boiling under a given pressure, will be found to differ at intermediate temperatures. We must, therefore, consider some other physical effect due to difference of temperature, and the only one known to be independent of the particular body operated on is the power of which we have just been speaking, which difference of temperature possesses of converting heat into work. If equal intervals of temperature be understood to mean equal capability of converting heat into work, we get a scale of temperature which may, with propriety be called *absolute*, and which as our investigation shows, coincides with that of the perfect gas thermometer, that is (sensibly) with the air thermometer; and the term "absolute," already applied to temperature measured in this way, is hereby justified.

(*To be continued.*)

THE EUROPEAN MEASUREMENT OF A DEGREE.

Translated Extract from "Allgemeine Bauzeitung."

The results obtained by the various measurements of a degree for the determination of the form of the earth, differ very considerably. In the several cases in which the method of least square was employed, values were obtained for that elliptic spheroid to which the figure of the earth approximates very closely. In this way Bessel from the results of 16 measurements found the oblateness,

$$0 = \frac{1}{299.1528} \pm 0.000039234$$

the length of semi-major

$$a = 3272077.14 \text{ toises};$$

that of the semi-minor

$$b = 3261139.33 \text{ toises};$$

the length of the degree of the meridian at the mean latitude ϕ,

$$l = 58013.109 - 286{,}337 \cos 2\phi + 0.611 \cos 4\phi + 0.001 \cos 6\phi \text{ toises};$$

the length of a degree of the parallel

$$l_1 = 57156.285 \cos\phi - 47{,}825 \cos 3\phi + 0.060 \cos 5\phi \text{ toises}.$$

Airy has made calculations based on 14 measurements and finds

$$0 = \frac{1}{299.33};\ a = 3272119.6.$$
$$b = 3261188.4.$$

These results differ little from those obtained by Bessel.

James's calculation of the length of the radius of the meridian circle at the latitude ϕ is interesting. Employing the formula

$$r = A + 2 B \cos 2 \phi + 2 C \cos 4 \phi,$$

and finding the values of A, B, and C, from the results of actual measurements, we have

$$A = 3267074.2; \; 2 B = 16820.1; \; 2 C = 244.3;$$

while to the elliptic form of the meridian correspond the values

$$A = 3266973.5; \; 2 B = -16681.8; \; 2 C = 35\ 5.$$

The agreement in these results warrants the conclusion that the figure of the earth is that of an ellipsoid of rotation about its minor axis.

After the completion of the measurement of the arc between Formentara and Dunkirk, France undertook and accomplished the measurement of about 13 deg. between Ravenna and Padua. For a mean length at 45 deg. 43 min. 12 sec. longitude, the result was 77862.6 metres; a deviation of 192.95 metres from the extreme value. On this account another survey was undertaken from Brest through Strasburg and Paris to Munich. The results have not yet been published. Another important survey was conducted by the Prussian General Müffling, which extended from the Observatory at Gotha, to Dunkirk. Two sections of this arc gave respectively an ellipticity of

$$\frac{1}{316.1} \text{ and } \frac{1}{315.2}$$

The most extended measurement was initiated by Struve. This extends from the east of Europe to the west of Ireland. It is nearly (1870) completed. The electric telegraph has been employed in determining the differences of longitude.

It is well known that the ellipticity of the earth has been determined by means of the pendulum; whose period of oscillation varies with the latitude and with the radius at the place of observation. The first experiments were made by Boguer; and the result was $0 = \frac{1}{35.5}$. Mathieu found $0 = \frac{1}{298.2}$ on the French meridian; while Sabine, from 25 observations between -13 deg. and 80 deg. latitude, found $0 = \frac{1}{289.1}$. Freycinct calculated $0 = \frac{1}{286.2}$ for the southern hemisphere.

The last European measurement of a degree will fill a gap in the former surveys; *i. e.*, between the Paris-Berlin-Dorpat meridians and between the longitudes of Palermo and Christiania. It will also contribute to the settlement of the question, whether the discrepancies in results are due to the irregular figure of the earth, or are to be accounted for by the deviation of the plumb-line. This deviation may be caused by the attraction of mountains, as was observed by Boguer in the Cordilleras, by Maskeleyne at Schehallien, by Maclear at the Cape of Good Hope, and by Carlini at Mount Cenis; or it may be due to different densities of the interior portions of the earth, as was assumed on the Italian plain; or to geologic diversities, as was conjectured in the Russian survey.

When the general figure of the earth has been determined, there still remain questions concerning local deviations, such as particular oblateness in different sections, different curvatures of the sea, etc.

THE HENDERSON PROCESS.

From "Engineering;"

About eighteen months ago attention was directed in many quarters to a process of subjecting pig iron to the combined action of fluorides and oxides, and it was asserted that by these means an exceedingly pure product could be obtained for use as wrought iron, or for conversion into cast steel of excellent quality, notwithstanding that the original cast iron, in respect of its phosphorus and other deteriorating ingredients, might have all the evil repute that attaches to Cleveland and other inferior classes of iron. Not much more was heard of the process for a time, but as it has been tried in this country, and on the Continent, within the past few months, and as we are in possession of some of the results of the experiments, we propose laying a brief statement regarding the process before our readers. From the title of this article, many of our readers will, naturally enough, and quite corectly, conclude that the process in question is the fluorine or fluorspar process, devised and patented by Mr. James Henderson, of New York, a gentleman who has done much for the development and extension of the iron manufacture in America.

Before coming to this country, Mr. Henderson had made many experimental investigations in American iron works. One plan of carrying out the principle of Mr. Henderson's patent is to use a mixture of finely-ground fluorspar and native oxide of iron in the pig bed, so that the iron from the blast furnace may be cast in plates or slabs about an inch in thickness, the intense heat of the iron during the process being sufficient to decompose the fluoride of calcium and oxide of iron, and thereby liberate fluorine and oxygen to act upon the silicon and phosphorus in their escape upwards into and through the liquid. We have lately seen this operation put in practice at the Summerlee Iron Works, Coatbridge, but we have not yet learned what sort of bar iron the resulting cast iron has yielded, nor if it has even been operated upon. In other experiments of a similar sort, however, Cleveland pig iron so treated has yielded at Walker Iron Works, on the Tyne (Messrs. Losh, Wilson, and Bell's), excellent bar iron, as indicated by the tests for tensile strength, made by Mr. David Kircaldy and by the analyses made by competent analytical chemists. And the same kind of treatment applied to foundry iron, at the Almond Iron Works, near Falkirk, in Scotland, produced according to Mr. Binnie, of the Falkirk Iron Works "very soft castings, and as solid as a bell." Forge iron treated in this way in the pig bed requires no further "physic," to use the language of the workmen in the puddling furnace; and when forge iron is used in the refined condition obtained by the use of fluorspar, the heats from the puddling furnace are got out in an hour on the average, including the charging, melting, puddling, balling-up, and removing from the furnace. The Henderson refined metal is stated to contain, as a rule, no silicon, owing doubtless to the extraordinary degree of affinity which fluorine has for that element—a degree of affinity which is familiar to every student of chemistry; and in respect of silicon and phosphorus it is affirmed to be as pure as wrought iron. If such results can really be always insured in practice, of course a most marked progress has been made towards perfecting the manufacture of iron; but we cannot shut our eyes to the fact that similar results have been claimed to have been effected by other chemical processes previously tried, but which have ultimately proved defective in practice.

Mr. Henderson does not limit himself to the treatment in the pig bed, as already briefly described; he also aims at effecting in the puddling furnace the complete process of purification, including decarbonization. Hitherto, however, he has used the puddling furnace alone, whereas that is the least economical method of operating. The plan which he aims at carrying out is to have a cupola furnace in which the pig iron is melted, and then run into one or more of a set of puddling furnaces surrounding it, and on the bed of each, of which the required quantity of fluorspar "physic" has previously been spread. It should be mentioned that, in addition to fluorspar, the patentee uses in the mixture he employs pure rich iron ores, ilmenite or titaniferous ironestone, clay, and carbonate of manganese in varying quantities.

The most elaborate series of trials made by Mr. Henderson are those which have just been concluded at Blochairn Iron Works, Glasgow. They extended, with one or two interruptions, over several months. Almost all brands of Scotch pig iron were operated upon, as also several brands of Cleveland iron. Many of the specimens obtained are now in the hands of eminent chemical analysts and Mr. Kirkaldy, and therefore we are precluded from saying anything regarding their chemical purity or mechanical properties; but the products have received a high character from many skilled practical men who have examined them. The process has also been approved by Messrs. Hannay and Sons, of Blochairn Iron Works, the most extensive manufacturers of finished iron north of the Tweed, and we understand that they have resolved to take a license from the patentee for working it. Clarence forge iron and Consett white cinder iron is stated to have yielded at Blochairn bar iron of the first quality; and Dalmellington No. 4 forge pig iron gave a product which, as a single-worked plate, flanged perfectly in the cold, and in which the sulphur was reduced to .04 per cent., and the phosphorus to .07 per cent., and in which the total impurities only amounted to .12 per cent. In all iron which has been subjected to a puddling process, however, so much depends upon the manner in which the puddling is performed, that it is difficult to found an opinion on a few isolated results.

Within the last few weeks, Mr. Henderson has brought his process practically under the notice of the proprietors of the Gilmont-Dupont Crespin Works at Blanc Misseron, in the North of France and of MM. Jowa and Cie., at Liege; and so satisfied were the proprietors of both works with the results, that they resolved to institute trials themselves on a large scale. The patentee operated upon Grosmont mottled pig iron, and is stated to have obtained No. 3, or best iron; on B. S. Newport, and obtained best, or No. 4, according to the French classification; and on Moselle pig iron containing 2 per cent. of phosphorus, and 1 per cent. of sulphur, obtaining from it finished iron classed as No. 3, or best.

More recently Mr. Henderson has had some of the bar iron which was made from mixed numbers of Clarence pig at Blochairn converted into cast steel at Messrs. Stones and Campbell's Steel Works, Govan, near Glasgow. The first sample of this product was pronounced excellent by Mr. Stones. If really good tool steel can by this process be made from Cleveland pig iron, and at a nominal cost, or, at all events, at not more than the ordinary cost, then Mr. Henderson is on the high road to achieve a reputation probably equal to that of Mr. Bessemer; but while we have every disposition to regard the fluorine process favorably, we require to be in possession of far more extended and exact data as to its practical capabilities before we can speak of it in the sanguine tone which is already adopted in some quarters concerning it.

REPORTS OF ENGINEERS' SOCIETIES.

Massachusetts Society of Arts.—At a recent meeting of the Massachusetts Society of Arts, the president J. D. Runkle, in the chair, Mr. Edmund H. Hewins read a communication, well illustrated by photographs projected upon a screen by the calcium light, on European and American bridges, and compared the cost and methods of building bridges in the two countries.

It is now generally acknowledged that the "truss" is the form which admits of the greatest economy in the use of material; and yet there are some engineers who cling tenaciously to the old plate or box girder. A few years since, an engineer of wide reputation and large experience condemned a truss bridge, giving as a reason that the peculiar construction would cause the iron to crystallize from the trotting of horses over it. The bridge was consequently built as a plate girder, and the cost was more than fifty per cent greater than it would have been for a truss bridge.

The days of tubulars, girders, etc., have substantially passed away; there will be no more Britannia or Victoria bridges; they stand as vast monuments of indomitable will and energy. All honor is due to Stephenson for building the bridge over the Menai Straits; considering the then limited knowledge of the use of iron in bridge building, it is a monument worthy to make his name famous for ages to come.

Brunel has done even more; the Saltash is a conception more gigantic, and as much a flight of genius—a work which will remain when the other is destroyed by time.

Truss and lattice bridges now predominate, the latter being but a form of the first.

The bridges of Europe are secured together by almost innumerable rivets; the various parts being usually composed of plate and angle iron riveted into box and other forms best calculated to resist the storms to which they may be subjected. The building of parts in this manner requires much care and is very expensive. The rivet holes deduct a considerable amount from the strength without reducing the weight.

A strut or tie composed of several pieces riveted together has not an effective strength proportioned to its section, for it is impossible to bring the different pieces to an equal strain at the same time. The engineer has here to make an allowance which is a very variable quantity. The ties and struts are rigidly connected with the chords.

Whenever a load comes upon a bridge there must be some deflection; this causes a distortion of the form of each panel, and as the ties and struts are rigidly connected to the upper and lower members, a powerful leverage to bend them is the result, and there is at the same time an increased strain upon the rivets.

In the crossing of a railway train or other partial load, the counters, neccessarily, not being in readiness to receive their proper strains at the proper moment, allow an undulation which materially increases the bending strains upon the ties and struts. This occurs every time a train or locomotive crosses the bridge.

The trusses used in American and European bridges are very similar, the essential difference being in details of construction, which in the European bridge are very expensive, as so much hand labor and fitting is required. A large amount of material is used which is mere dead weight, being of no use in sustaining the load or itself. The action of such a bridge is necessarily unsatisfactory from the fact that certain portions receive strains in practice which are not legitimate, and consequently must tend to shorten its life.

The following data were collected in Europe by Mr. David Busk. The viaduct of Fribourg, on the Orleans railroad in France, is composed of eight spans of 160 ft. each, and has a height of 250 ft. above mean low water of the Sarine. The piers have a masonry foundation 89 ft. high, with a metallic superstructure of 142 ft. The total length of the viaduct is 1299,88 ft. and cost, above the masonry, $366,000 in gold, or $282 per lineal ft. The figures for three other viaducts on the Orleans Railroad are as follows:—

The viaduct of the Bouble.

6 spans of 164 ft. each, total length	984 ft.
Height above masonry, average	138.76 ft.
Cost per lineal ft.	167 dols.

The viaduct of Bellou.

3 spans, average length 140 ft., total	420 ft.
Height above masonry	137.76 ft.
Cost per lineal ft.	123 dols.

The viaduct of Neuville.

2 spans of 161.13 ft. each, total length	322.26 ft.
Height above masonry	136.18 ft.
Cost per lineal ft.	112 dols.
1 span	77.08 ft.
Cost per lineal ft.	108 dols.

The American Truss Bridge instead of being bound together in one solid mass, is composed of various members, each independent of its neighbor, so far as it own work is concerned, each having a specific and defined duty to perform, and proportioned accordingly. By no change of temperature, or variety of loan in amount or position, can any but legitimate strains be imposed upon any part. The joints are made with pin connections, so that a deflection can bring no twisting or bending strain upon any of the parts—and though the form of each panel be very much distorted by an approximation to the breaking load, no excess over the proper strain can be brought to bear on the bridge. Each part is known to receive its proper strain at the proper time, as they are made adjustable in all directions, and by this means the vibration and undulation are reduced to a minimum. American bridges have astonished the world that such light structures should have so little deflection and undulation.

American bridges are cheap to build. Most of the work is done by machinery instead of hand labor, and but little skilled labor is required.

Work done by machinery does not cost one half as much per pound as work done by hand. Considerable expense is also saved in handling and erection.

It is sometimes necessary to erect bridges over streams which are liable to rise suddenly and sweep away the temporary works. In such a case, the loss would be incalculable in time and money, if the bridge should be carried away.

Our bridges—built as they are in parts which are seldom too heavy for two or three men to handle—can be erected in a very short time.

A 200 ft. span could be swung clear of the staging in three or four days, while the plate girder lattice, or European truss would require as many weeks. The average cost of railroad bridges in America is about one half as much in currency as European bridges cost in gold.

ROYAL INSTITUTE OF BRITISH ARCHITECTS.—A Paper was read by Captain Seddon (R.E.), On the Necessity and Method of Testing Building Materials. He contended that the most successful architect or engineer was he who obtained the most successful results with the least expenditure of money and labor. The great problem of the day was, how most successfully to economize money and labor. The extensive use of iron for constructive purposes might be said to have given birth to civil engineering, in contrast to architecture, and this had been attended with somewhat disadvantageous results. Perhaps architects had confined themselves too exclusively to the study of the beautiful, and engineers, affecting a superiority for such ideas, had too much neglected art. There was also a ministerial authority for banishing art from ordinary structures, and confining it only to churches. Whilst there was necessarily a radical difference between engineering and architecture, he thought the members of both professions would do better by working more together. In striving to obtain the best results from the least outlay of money and labor, architects and engineers both stood on the same footing; but it was a question whether they were sufficiently acquainted with the properties of the different materials which they employed. It might be said that there were handbooks in existence giving all needful information about materials and their properties; but he thought it must be admitted that their knowledge was not so satisfactory as could be wished. Experiments had mostly been tried on specimens which were too small, or were defective; and the results, therefore, were not reliable. Molesworth, the author of a handbook on Engineering Formulæ, differed considerably from Hirst, who had compiled an architectural handbook respecting the tensile strain of materials; and there was, in fact, a mass of conflicting evidence on such subjects. Even the seasoning of the specimens tested would account very much for the different results arrived at, and a natural adhesion of the fibres made a vast difference. Notwithstanding the experiments and researches of Mr. Kirkaldy, it was clear that there was yet a great deal to be learnt about iron, and misconceptions prevented what could only be swept away by a series of practical experiments. Iron was now forcing its way everywhere; and it was requisite that they should not merely order a girder, but also be thoroughly acquainted with the material, as there was nothing so dangerous to trust to as iron, and no material which admitted of so much deception on the part of the dishonest manufacturer. The different strength and properties of various descriptions of iron were remarkable. In order to insure having a proper kind of iron, they should get it tested beforehand; the elasticity and ductility of the metal must be ascertained, in addition to its compressive and tensile strength. Many obsolete notions about iron were still retained, and cold grey iron was supposed to be required for particular purposes; but they did not get it from the contractors. The effect of different degrees of temperature upon the ductility of iron was worthy of inquiry. When subjected to great heat, iron would lose its ductility; and it was injurious to expose a hard metal to extreme cold. In the forging of iron rivets great attention was necessary, and they were liable to be injured by remaining in the fire too long. With regard to wood, he called attention to various experiments which had been made on large sections, and the results, he thought, would be different from those arrived at in experimenting on 2 or 3-in. specimens. In testing building stones the recorded results differed very widely, so that if they trusted to a handbook, the strength of their materials might be supposed to depend upon what particular work they consulted. A preference was frequently exhibited for Coreham Down stone over Boxford ground stone, but it was doubtful whether any superiority existed; only one description of stone was more expensive because it was more difficult to procure. The artificial dressing of stone should not be resorted to. With regard to the strength of sandstones, the information upon the subject was very meagre and unreliable; and it was clear that more knowledge was required respecting the special qualities of different kinds of stone and their applicability to different uses. In experimenting upon stone, they ought to know all about it—the quarry where it came from, and perhaps even the particular bed in the quarry. He also advocated a careful series of experiments upon the artificial stone called concrete, which he believed would be very useful; and contended that architects should do all in their power to carry out a careful course of experiments for the purpose of testing the various materials they employed, as by these means all doubts and doubtful theories might be cleared away, and conclusive results obtained. He would recommend a visit to Mr. Kirkaldy's testing works at Southwark; his machinery was so perfect, that his experiments might be depended upon. It was by men of Mr. Kirkaldy's stamp that the world had been benefited; but the world often forgot its benefactors. Then came the question, who should pay for the experiments? He replied—the manufacturers, and those who wished to supply materials; they ought to send them to Mr. Kirkaldy's works to be tested beforehand. The cost of the experiments would then fall upon the right shoulders, and he believed this plan had been already carried out to some extent.

Association of Engineers in Glasgow.—At the monthly meeting of this Association—the President, Mr. John Sutherland, in the chair—Mr. Alexander Reid read a paper on "Time Allowances for Yachts in Racing," in which he alluded at considerable length to the various methods employed in computing the scales of allowances in this country and in different parts of America. The principles on which these various scales are constructed were carefully examined, and the insufficiency of most of them to meet all cases clearly shown. It was maintained that, as the most correct means, the allowances should be made in proportion to the displacement of the vessels. A discussion followed the reading of the paper, in which there was much interest taken.

Paris Society of Civil Engineers.—At a recent meeting a report was received from M. P. Thomas, which he had been instructed to make on the new oxyhydric light of M. Tessie du Motay. The report is limited to a technical examination, apart from the ecconomical question, and the following are the conclusions arrived at:—1. Theoretically, the combustion of oxygen does not increase the illuminating power of a given volume of gas. 2. Practically, however, it enables a burner to consume four times the quantity of gas that can be burnt in air, without detriment to the utilization of the light developed. In particular, it realizes the entire luminous capacity of gases, however rich, in almost any quantity.

Consequently, it would be disadvantageous to supply it for ordinary street-lighting, on account of the limited consumption of the burners in use.

Its use presents no other great advantage, except as to the beauty of the light, for small burners supplied with very rich gas.

But it is very advantageous—and the more so in direct proportion to the richness of the gases employed—for great centres of light (sun-burners, etc.), where a large volume of gas my be consumed without loss. With reservations in relation to the proportion of the total quantities of gases consumed (oxygen and hydrogen) and the resulting illuminating power developed.

The foregoing is not the only report to be made upon the subject, as M. Leblanc, it is understood, is commissioned to report thereon for the city authorities.

The Royal Society.—The "Decomposition of Water by Zinc in conjunction with a more Negative Metal" was the title of a paper by Messrs. J. H. Gladstone, Ph. D., and Alfred Tribe, F. C. S. Pure zinc is incapable of decomposing pure water, even at 100 deg. Cent., but at a considerably higher temperature it is known to combine with its oxygen. Davy exposed pure water for two days to the action of a pile of silver and zinc plates, separated only by pasteboard, without obtaining any hydrogen; Buff, however, had shown that a very minute trace of gas can be formed at the ordinary temperature by a pair of zinc and platinum plates. By bringing the metals close together, and thus increasing the electrical tension of the liquid, the authors could effect the same combination of zinc with oxygen at the ordinary temperature which takes place, without the second metal at a very high temperature. On thin sheets of zinc and copper being hammered together, and placed in a bottle filled with distilled water, small bubbles of gas were formed; the same result obtained when the experiment was tried in a more perfect form. Under the microscope the bubbles of gas are seen to form, not on the zinc, but among the copper crystals, and sometimes to make their appearance on the glass at some distance off. Lest it might be contended that the free oxygen usually present in distilled water had been the means of starting this action, the experiment was repeated with water as free from oxygen as could be obtained by boiling. Iron and lead under similar circumstances, also decomposed pure water, and the action of magnesium was greatly increased by conjunction with copper. The effect of the more negative metal was the same as would have been produced by an increase of heat. From a practical point of view this experiment may serve as a ready means of preparing pure hydrogen; from a theoretical point of view its interest seems to lie in the fact that the dissociation of a binary compound by means of two metals may take place at infinitesimally short distances, when it would not take place were the layer of liquid enough to offer resistance to the current, and also in the correlation between this force and heat.

IRON AND STEEL NOTES.

British Iron Trade.—It is a matter of great interest to the British iron trade to inquire what are the future prospects of the American demand for British iron, and especially British railway iron. The exports of our railway iron to the United States in the first three months of this year compared as follows with the exports of the corresponding periods of 1871 and 1870:

Month.	1870.	1871.	1872.
	Tons.	Tons.	Tons.
January....	24,610	28,264	28,648
February...	32,957	32,784	53,131
March	23,222	41,917	41,175
Total....	80,789	102,965	129,605

It will be seen that while the exports presented a slight advance in January, as compared with January, 1871, and a considerable advance in February, as compared with February, 1871, they reflected in March a slight check in the American demand for our railway *materiel.* The question of questions, which now awaits solution, is whether this check is attributable to the higher and higher prices which have gradually become current for British iron, and whether, under the circumstances now existing, the Transatlantic demand is likely to be maintained at its present or former level. The gravity of this question will at once be seen by the annexed analysis, indicating the proportion borne by the exports of our railway iron to the United States to the corresponding exports in all directions:

Quarter ending March 31.	1870.	1871.	1872.
	Tons.	Tons.	Tons.
Whole export...	209,151	174,479	201,321
To United States	80,789	102,965	129,605
Balance.....	128,362	71,514	71,716

These figures indicate two results—first, the extreme relative importance of the American demand; and secondly, a great falling off in the general external demand for our railway iron. There can, we fear, be only one conclusion formed from an examination of the statistics, viz., that high prices are producing their usual inevitable result of restricting consumption. It is time, in short, that the British iron trade—and especially the operative members of it—should understand that quotations for iron cannot go on advancing forever, without frightening away intending purchasers. * * * * * * *

The dearness of English iron would appear to have given a great impetus to the production of iron in the United States. In 1871, the make of pig iron in the great Republic was estimated at 1,912,608 tons; this total was scarcely so large as the corresponding figures for 1869; but when we go back to 1861, we see that very great progress has been made in the manufacture of American pig iron, the output for 1861 having been only 731,544 tons, or considerably less than one-half the total attained last year. In 1871, the United States imported 572,386 tons of rails, of which 511,059 tons were supplied by Great Britain, the balance of 61,327 tons being obtained principally from Belgium. In the same year, the Americans made themselves 775,733 tons of rails, four states supplying more than 50,000 tons each, viz., Pensylvania, 335,604 tons; Illinois, 91,178 tons; New York, 87,022 tons; and Ohio, 75,782 tons. The Americans possess almost inexhaustible supplies of coal and iron minerals, and their metallurgical industry, already important, might acquire, in a few years, a very great development, if prices continued high in Europe. The Americans have not imported large quantities of English rails because they cannot make rails for themselves, but simply because it has hitherto been cheaper to import rails from Great Britain than to make them —at any rate, in every case—at American rail mills. Destroy the cheapness of English railway material, and you cripple and restrict the market for it in the United States; and not only the marked for it in the United States, but the market for it throughout the world. This is a consideration calling for the most earnest attention on the part of all connected with the British iron trade.—*Colliery Guardian.*

German and French Steel.—The "Bulletin of the French Committee of Forges" gives an interesting comparison on the production of steel in Germany and France. The former country produced, in 1860, 25,312 tons, and in 1869 not less than 163,319 tons of cast steel, being 6.37 times more than 9 years before. From 1864 to 1869 France, however, saw her production of steel, principally Bessemer steel, multiplied 29 times, which was in 1869 actually 52,000 tons. The first half year of 1870 shows a production of 44,419 tons, and when the steel industry of France shall have overcome once more the difficulties which it has suffered under the war, her annual steel product may be estimated at 90,000 tons. Germany increases her number of steel works almost daily, and will most likely remain ahead of France for some good time to come.

The Terrenoire Works are stated to have forwarded steel rails to the United States last year to the value of $150,000. This is believed to be the first occasion upon which French works have established business relations with the American railway interests.

The territory ceded by France to Germany contains 25 blast-furnaces, producing annually 555,000 tons; and 9000 hectares of coal and ironstone beds, of a yearly yield of 180,000 tons. An iron-masters' association in the Longwy district contemplates the erection, in France, of new works.

RAILWAY NOTES.

WHARTON RAILWAY SWITCH.—This new thing under the sun presents many desiderata, indispensable to such appliances for assuring, at once, safety, economy, and ease of operation.

Prominent among its excellencies is the fact of its granting switch facilities *without breaking the main line* and endangering through travel. For those unacquainted with the peculiar difficulties besetting the accomplishment of such an object, the above statement may not carry weight; but to experienced railway men it is interesting and valuable.

In construction, this switch is simple and peculiarly enduring,—all the wearing parts being of solid steel and only borne upon by cars entering or leaving sidings, the main track (by a peculiar and new arrangement) being used exclusively by the trains running over it without in the least affecting the "switch track." In practical operation it affords what is still more valuable, viz.: perfect security to trains in case it is left wrong, either accidentally or by malicious design, —for your switch-tenders will sometimes take a fancied revenge upon their employers by such dastardly means, and in all such cases no injury is done to the switch itself. Targets and signals, moreover, for indicating the position of the switch on double-track roads, are dispensed with; while on single-track roads it wil not remain set for a siding, should the tender forget his duty.

Without diagrams it is almost or quite impossible to convey any full idea of the movements of this invaluable invention; and we are compelled to forego a detailed description of it for that very reason. In general, however, we call attention to one rather important feature: None of the accidents heretofore so frequent from the bending or breaking of connection-rods, or of any of the moving parts, can possibly ensue in the use of the Wharton switch, since the main track is absolutely immovable (being spiked to the cross-ties), and for other reasons unexplainable without illustrations.

This invention is presented to the public with the commendations of several practical railway managers—prominent among them being Hon. Thos. A. Scott, of the Penn. R.,—who attest its trustworthiness. Mr. Scott certifies: After careful "experiment upon our road at several points where it could be *most thoroughly tested,* we think it adapted to all our wants. We have concluded to adopt it on our own and our leased roads, and will give it place as rapidly as we can. I believe it will prove of great practical value to all railways."

Such an indorsement has valuable significance both to the owners of the invention and to a grand army of railway builders or projectors.

AN IMPORTANT PENNSYLVANIA NARROW GAUGE.—In pursuance with the charter, the Montrose Railway Company was organized April 27, 1871. At the first meeting of the Directors, May 27, 1871, it was directed that the engineers survey and locate from Tunkhannock to Montrose. The report of its President, James L. Blakslee, Jan. 8, ult., shows a favorable prospect for the completion of the road by August next. The Lehigh Valley Railroad Company has agreed to furnish the rails, ties, spikes, and splices as soon as the grading has been completed and paid for; agreeing, also, to receive their pay in stock at par.

The Engineer reports that the survey commenced May 15, 1871. The work is now under contract and progressing favorably. Length of road, 27 $\frac{12}{100}$ miles. Commencing at Tunkhannock, the first summit is found at 4$\frac{26}{100}$ miles; average ascending grade per mile (excluding levels), 93 ft.; the next summit is 7$\frac{25}{108}$ from Tunkhannock, ascending grade 26 ft.; the grade then descends to Meshoppen Creek, 10$\frac{15}{100}$ miles, with average descent of 40 ft. per mile. The next summit is 16$\frac{29}{100}$ miles; average ascending grade from Meshoppen Creek, 85 ft. From this summit this grade is level for 1 mile. From this to the next, 19$\frac{45}{100}$ miles, the average ascending grade is 71 ft. per mile. From there to the next summit (23$\frac{54}{100}$ miles from Tunkhannock), the grade is undulating, nowhere exceeding 85 ft. ascent and 63 ft. descent. From the latter to Montrose it is also undulating, nowhere exceeding 80 ft. ascent and 60 ft. descent. There are two 18 deg. curves—all the others being only of 16 deg. There will be two bridges, each of 100 ft. —one spanning the canal at Tunkhannock and the other, Meshoppen Creek. Also 600 ft. of trestling of average height of 26 ft. The road is under contract to be built ready for track laying for $101,000, which sum can be taken for approximate cost of grading, masonry, bridges, etc. The estimated cost per mile is $5,733. Total cost, including rolling stock, equipments, station houses, etc., $341,478. The gauge adopted is 3 ft. Says the President, in summing up:

The probabilities of this road paying fair dividends can be inferred from the following facts:

It passes through the centre of the populous county of Susquehanna, which is a rich agricultural region, with but little waste land. The farms are all well improved and the land is specially adapted to dairying and grazing. The road makes available the valuable water power at the outlet of Marcy's pond, and on the Meshoppen Creek. It runs into the borough of Montrose, the county seat of Susquehanna county, which is a flourishing business and manufacturing centre, and has no other railroad communication.

Estimate of the annual revenue and expenses:

From freight on 12,000 tons of coal, at $1.25...		$15,000
On 12,000 tons lumber and bark, at $1.00.....		12,000
On 12,000 tons miscellaneous, at $1.60........		19,200
From passengers...........................		12,000
From mail and express......................		4,000
Total		$62,200
For operating and maintaining road, etc..................................	$28,000	
For dividends, 10 per cent. on the capital of 342,000	34,200	
		$62,200

THE RAILWAY INTEREST.—It has lately been shown that 14,247 miles of railway are now being worked in the United Kingdom, on which have been expended a sum of more than £500,000,000, which is 5 times the amount of the annual value of all the real property of Great Britain, and $\frac{2}{3}$ of the national debt. The gross net annual revenue of the railways in this country, after deducting all working expenses, exceeds £22,000,000, more than the total revenue from all sources of Belgium, Holland, Portugal, Denmark, Sweden, and Norway. The companies have in their direct employment more than 100,000 officers and servants. The value of the rolling stock exceeds £30,000,000. The consumption of coal and coke by railway engines amounts to between 2,000,000 and 3,000,000 tons a year; so that in every minute of time throughout the year, above 4 tons of coal are consumed, and 20 tons of water are flashed into steam. The consumption of fuel is about equal to the amount of coal exported from Great Britain to foreign countries. There are more than 3,000,000 tons of iron laid down in rails alone, and the chairs would weigh nearly 1,000,000 tons; so that there are not far short of 4,000,000 tons of iron on the permanent ways of the United Kingdom, and of these about 30,000 tons of rails have to be every year replaced. No one will deny that our railways make a figure in the world.

ENGINEERING STRUCTURES.

The Tunnel under the Mersey.—The tunnel which is to connect Birkenhead and Liverpool has been commenced. The trade in the Birkenhead Docks has been very much retarded for the last few years, and prevented from ever attaining its proper dimensions by the want of sufficient means for the transit of goods from Liverpool. The tunnel according to the "Birkenhead and Cheshire Advertiser," will be about 3 miles in length, about one-third of which will be under the bed of the river Mersey, and will connect nearly all the railways in England with the Birkenhead Docks. The preliminary operations for the formation of the tunnel have been completed. A hoarding has been erected on the South Reserve land, between Shore-road and the river, close to Woodside Ferry, and on Monday a number of workmen commenced preliminary operations for sinking a shaft in order to attain a depth of 70 ft. below the bed of the river, at which point the cutting of the tunnel railway will be undertaken. The tunnelling will be performed with two machines, each of which will make a cutting 15 ft. in diameter with a pressure of 30 horse-power engines. Two other shafts will be sunk on the Birkenhead side, one on the upper side of Shore-road, and the other between the gasworks and Green-lane, Tranmere, where will be situated what may be called the Cheshire terminus, the line there joining the Birkenhead and Cheshire railway, thus giving direct access from London into Liverpool, under the Mersey. As most of the materials dislodged in the cutting will be brought to bank at Birkenhead, it will be some time before the work commences on the Liverpool side, the only materials to be brought up there being those displaced in the downward shaft, which will have to be driven in order to reach the eastern end of the tunnel. This will be next the Harbor-master's office. It is anticipated that, unless serious geological "faults" are met with, the cutting of the tunnel, which is to accomodate a double line of rails, will be completed in two years.

Railway Bridges in Canada.—We have the following from the Toronto "Globe:"

"Survey and soundings are completed for the proposed railway bridge over the Ottawa River, above the Chaudiere. A very feasible route gives a bridge 3,400 ft. long, 2,000 ft. of which will be on land at low water, not over 5 ft., and the depth in the channel is less than 20 ft.

"The engineers employed in taking soundings for the proposed bridge across the St. Lawrence, between Prescott and Ogdensburg, have completed their labors. The bridge will be 3,000 ft. long, and the piers will have to be sunk in 80 ft. of water."

Rosendale Viaduct.–A magnificent iron bridge at Rosendale, N. Y., begun in September last, is completed. It carries the Wallkill Val. R. across the valley of Rondout Creek and over the Del. & Hudson Canal, running through it. The country being mountainous, the bridge is necessarily put at a very great height above the level of the valley; giving to the structure a picturesque appearance, while its substantial workmanship allays the apprehensions of the most timid traveller.

The superstructure is of the undergrade or "deck" kind; comprising seven wrought iron spans of the Post patent, with two short wooden spans at its south approach. Of the iron spans, respectively, four are 150 ft.; two, 100 ft.; and one, 76 ft. long; the two of wood being each 50 ft.—a total of 976 ft. The trusses are 22 ft. high and 14 ft. apart. A moving load of 3,000 lbs. per lineal foot of bridge, together with the weight of the structure itself, does not tax the bridge to more than one-sixth its capacity. The spans rest on piers, each made up of 6 rectangular wrought-iron pillars trussed with diagonal bracings, arranged so as to obtain the greatest possible rigidity; the iron piers resting upon solid masonry. The height of the bridge between grade line and the water is (at the highest point) 142 ft. The piers are, respectively, 14, 80, 100, 145, 80, 65, and 35 ft. from the ground to underside of the truss. The iron part weighs about 585 tons,—385 distributed among the different spans and the rest among the piers. The cost is: Ironwork about $175,000, and masonry about $50,000.

BOOK NOTICES.

Science Primers for Elementary Schools. Under the joint editorship of Professors Huxley. Roscoe, and Stewart. (In 18mo, cloth limp, 50c. each.) Macmillan & Co., 1872. For sale by Van Nostrand.

Of this interesting series of little books, three have appeared, and the announcement of others is shortly promised. We have an introductory discussion by Professor Huxley, and the set of manuals commences with Chemistry by Professor Roscoe, and Physics, by Dr. Balfour Stewart. We are informed that in publishing the Science Primers on Chemistry and Physics,the object of the authors has been to state the fundamental principles of their respective sciences in a manner suited to pupils of an early age. They feel that the thing to be aimed at is not so much to give information, as to endeavor to discipline the mind in a way which has not hitherto been customary by bringing it into immediate contact with Nature herself. For this purpose a series of simple experiments has been devised leading up to the chief truths of each science. These experiments must be performed by the teacher in regular order before the class. The power of observation in the pupils will thus be awakened and strengthened; and the amount and accuracy of the knowledge gained must be tested and increased by a thorough system of questioning.

This is a novel and ambitious programme: but when Professors Huxley, Roscoe, and Stewart lay their heads together for the production of educational hand-books, something unusual may be expected. Hence, in the little volume of Chemistry, of little beyond a hundred pages, the reader's mind is led step by step from the consideration of one of the simplest processes—the burning of a candle—up to that of chemical proportions, weights, combinations, and equations. For the results aimed at, this method is perfect, and takes the learner through familiar departments, designated fire, air, water earth, non-metallic elements and metals.

Similarly, in Professor Stewart's little volume, the same gradation in the nature of the experiments is kept in view successively through the discussion of natural forces, solids, liquids, gases, motion, vibration, heat, and electricity.

We are certain that in the manner followed, the alphabet of science may be taught to school-boys, and the means of intelligent observation afforded in a way that has never been hitherto exhibited. This is infinitely superior to the meagre and ill-digested smattering of all the sciences conveyed in too many schools and popular lectures.

Atchley's Estimate and Price Book for 1872. By W. Davis Haskoll, C. E. etc. Lockwood & Co. For sale by Van Nostrand.

This valuable work maintains its character. Of the amount and diversity of its contents a fair account is embodied in the title-page, running thus: —Atchley's Civil Engineer's and Contractor's Estimate and Price Book for Home and Foreign Service; in reference to Roads, Railways, Tramways, Docks, Harbors, Forts, Fortifications, Bridges, Aqueducts, Tunnels, Sewers, Water-works, Gas-works, Stations, Barracks, Warehouses, etc., etc., etc. With specifications for Permanent Way, for Telegraph Materials, and for Works, Plant, Maintenance and Working of a Railway; and an Alphabetical Priced List of Machinery, Plant, Tools, and Fittings required by the Contractor in the execution of Public Works. The work is well printed on above 200 pages (demy 8vo). There are 30 woodcuts and 3 full-page plates. From obvious causes, books of this class are almost invariably high-priced; this, on the contrary, is uncommonly cheap, and therefore may fairly demand that extensive circulation among intelligent workmen which its merits so highly deserve.

Advanced text-book of Geology: Descriptive and Industrial. By David Page, LL. D., F.G.S. etc. Fifth edition, revised and enlarged. Wm. Blackwood and Sons, 1872. For sale by Van Nostrand.

The first edition of this admirable work appeared sixteen years ago. It has raised its author from the position of an altogether extra-academical man to that of Doctor of Laws, and to the yet more honorable and important position of Professor of Geology in the College of Physical of Science, Newcastle University of Durham. It is beyond all comparison the best text-book for learners in geology which was ever written in any language. In the short preface to the present edition, Dr. Page says:—"This edition has been enlarged, 1st, to embrace whatever is new and important in the science; 2d, to afford space for additional illustrations; and 3d, to combine, as far as possible, the principles with the deductions of geology. We reason our way to the past through our knowledge of the present, and our descriptions of former epochs become more intelligible and impressive when viewed through the medium of existing phenomena. For this purpose there have been inserted such notices of operations now in progress as seem to bear on the subjects under review—and this in subordinate type, and in such a form as not to interfere with the continuity of the original textual arrangement. These small-type paragraphs should be read with care by the student, for in them he will frequently find the key to the geological problem he is endeavoring to unravel. On the whole it has been the aim of the author to improve rather than enlarge—to keep the volume abreast with the latest discoveries and advancing views of our leading geologists, and yet to prevent it from exceeding the limits of a compendious text-book." The illustrations, the text, and the valuable glossary and index, all bear traces of extension and improvement.

The Chemical Phenomena of Iron Smelting. By I. Lowthian Bell. London: E. & F. N. Spon. One volume, octavo, 435 pages, cloth, $6.00. Sent post paid by mail on receipt of price. For sale by D. Van Nostrand.

The character of this excellent work may be judged from the essays of Mr. Bell republished in this magazine, fron the "Journal of the Iron and Steel Institute."

The thoroughly scientific character of the treatise, entitles it to a high position in technical literature, while the great importance of the subject will demand that all who have even the most general interest in the progress of practical science should acquaint themselves with the investigations of Mr. Bell.

In evidence of the thoroughly practical character of the work, we quote the following from the "London Mining Journal:"

"The reactions which take place in every foot of the blast-furnace have been investigated, and the nature of every step in the process, from the introduction of the raw material into the furnace to the production of the pig iron, has been carefully ascertained, and recorded so fully that any one in the trade can readily avail themselves of the knowledge acquired; and we have no hesitation in saying that the judicious application of such knowledge will do much to facilitate the introduction of arrangements which will still further economize fuel, and at the same time permit of the quality of the resulting metal being maintained, if not improved. The volume is one which no practical pig iron manufacturer can afford to be without if he be desirous of entering upon that competition which nowadays is essential to progress, and in issuing such a work Mr. Bell has entitled himself to the best thanks of every member of the trade."

Dilapidations: A Text-Book for Architects and Surveyors.—Mr. Banister Fletcher has revised and reprinted, in a neat volume, his series of articles on dilapidations which appeared in the "Building News" the latter part of last year, and has added thereto a list of the cases cited, an elaborate analysis of contents of each chapter, and an exhaustive index. The work shows who are liable for dilapidations, what are dilapidations and waste, and instructs surveyors how to take and value them; it is illustrated by examples drawn from the author's experience, and gives the latest legal decisions. It is, in fact a text-book and a standard work of reference for the architect and surveyor on matters appertaining to dilapidations. For sale by Van Nostrand.

ANNUAL RECORD OF SCIENCE AND INDUSTRY FOR 1871: Edited by Spencer F. Baird. New York: Harper & Brothers. For sale by Van Nostrand.

This is designed to fill the place of the "Annual of Scientific Discovery," the publication of which is discontinued.

To the scientific reader or writer, such a yearly record is indispensable.

The matter and its arrangement is substantially the same in character as that of the Annual, with whose features we have been so long familiar.

The typography of the present volume is an improvement upon that of its predecessor.

It is to be hoped that the success of the Record will be such as to encourage the publishers to continue the series.

A TREATISE ON RAILWAY CURVES AND LOCATION. By E. W. Beans, C. E.: Philadelphia: Henry Carey Baird. For sale by Van Nostrand.

This little book contains a series of propositions covering such properties of the circle as are generally employed by railway engineers in the location of curves. It contains but little that is new, and nothing that we could consider an improvement upon the matter already in print in American Field books. The methods given are concisely stated, but are lacking somewhat in logical arrangement. The illustrations are abundant and good.

SPECTRUM ANALYSIS EXPLAINED. Profs. Schellen, Roscoe and Huggins. Boston: Lee and Shepard. For sale by Van Nostrand.

This is No. 3 of the "Half-hour Recreations in Popular Science." We know of no form in which so much sound information is afforded for the price, as in this new series of pamphlets. The present number will probably prove the most attractive thus far to the general reader, containing as it does a complete exposition of this most fascinating department of research, with elegant illustrations.

MISCELLANEOUS.

ALLOYS.—M. Gurttier, in his work on metallic alloys, gives the following directions, which are very valuable, as they are the results arrived at after large experience.

1. To heat the crucible to a red or sometimes a white heat, and then to melt the *least* fusible of the metals composing the alloy. After fusion to heat this metal to such a heat, that it will bear the addition of the next least fusible metal without too great a reduction of temperature.

2. To introduce the metals into the pot strictly in the order of their resistance to fusion, each metal being properly melted before the next is added. The danger in first melting one of the most fusible metals lies in the fact that it would most probably volatilize and become oxidized; this would be a source of great waste.

3. To heat each charge of metal thoroughly before adding it to the pot, thus avoiding as far as possible the reduction of the temperature of the metal in the crucible.

4. When the proportion of zinc is large and some of the component metals have a high point of fusion, the alloys should be covered with a layer of charcoal dust. If the alloys are rich in tin, the surface of the melted metal should be covered with sand.

5. To stir the metal before casting, and if possible when casting, with a white-wood stick; this is much preferable for the purpose to iron.

6. If possible, to add a small proportion of old alloy to the new one. If the alloy is required to make sharp castings, and strength is not a very great object, this proportion of old alloy to the new should be increased. In all cases a new, or thoroughly well cleaned crucible should be used.

STAINING IVORY.—Having seen queries in "Ours" relating to this subject, and having some experience in it, I append a few directions which may be useful to some of "our" readers.

Black.—Lay the article for several hours in a strong solution of nitrate of silver, and expose to the light, or boil the article for some time in a strained decoction of logwood, and then steep it in a solution of acetate of iron. An easier method: immerse frequently in ink until of sufficient depth of color.

Blue.—Immerse for some time in a dilute solution of sulphate of indigo, partly saturated with potash, and it will be fully stained.

Green.—Boil in a solution of verdigris in vinegar until the desired color is obtained.

Red.—Dip the articles first in the tin mordant used in dyeing, and then plunge into a hot decoction of Brazil wood—half a pound to a gallon of water—or cochineal, or steep in good red ink until sufficiently stained.

Scarlet.—Use lac-dye instead of the preceding.

Violet.—Dip in the tin mordant, and then immerse in a decoction of logwood.

Yellow.—Impregnate with nitro-hydrochlorate of tin, and then digest with heat in a strained decoction of fustic, or steep for 24 hours in a very strong solution of the neutral chromate of potash, and then plunge for some time in a boiling solution of acetate of lead.

Horn and bone must be treated in the same manner as ivory for the various colors given above.

HARDENING STEEL CUTTING TOOLS.—The best way is to heat the articles in a coke fire to a blood red heat, and then plunge them into a solution of salt and water, containing one pound of salt to a gallon of water; then polish the articles, heat them over gas or otherwise, till the polished parts assume a pale straw or gold color, and then cool them in the salt and water, if this is well managed, it will make tools to cut anything. The lead process is generally used for hardening files. Best tool steel would not harden by the lead process and stand tempering. Coke fire is generally used for tools for cutting purposes, and I think this process will best answer the purpose.—*Correspondent Mechanics' Magazine.*